VEIRS

Pneumatic Tools

Mechanical Engineering

B. S.

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PNEUMATIC TOOLS

..BY..

DAVID CARROLL VEIRS

THESIS

FOR THE DEGREE OF BACHELOR OF SCIENCE IN

MECHANICAL ENGINEERING

IN THE

COLLEGE OF ENGINEERING

OF THE

UNIVERSITY OF ILLINOIS

PRESENTED JUNE, 1901

1901
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May 31, 1901 190

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

David Carroll Veirs

ENTITLED Pneumatic Tools

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Mechanical Engineering.

L. P. Breckenridge

HEAD OF DEPARTMENT OF Mechanical Engineering.

UIUC

HISTORICAL REVIEW OF THE USES
of
C O M P R E S S E D A I R.

The first authentic patent for compressed air machinery was taken out in England in 1726 by Rowe. From that time up to the beginning of the 19th century there were many attempts to pump water by means of slightly compressed air.

In 1799 Medhurst took out a British patent to compress air for motive power by means of a wind-mill, and in 1828 Bompos in a provisional British patent proposed to propel locomotives by compressed air. In the same year Colladon proposed to employ compressed air in the Thames tunnel.

However, the first decided advance in the science of compressed air and its applications was made by Wm. Mann. In his patent he states by application of compressed air, power and motion can be communicated to fixed machinery, carriages, locomotives and ships. In the description of his method of compressing air, he says: "The condensing pumps used in compressing the air I make of different capacities, according to the density of the fluid to be compressed, those used to compress the higher densities being proportionally smaller than those previously used to compress it at the first or lower densities." It is evident from this extract that Mann discovered the advantage of compound compression.

In 1836 James Surrey in a British patent suggests portable vessels filled with compressed air for the use of railways; he also

4063-4

suggest a central compression plant with a system of piping between stations.

In 1844 Arthur Parsey patented a regulating device between the receiver and the cylinder.

In 1847 Von Rathen in an English patent describes the processes of wet cooling and jacket cooling; he also describes a refrigerator for cooling the air after compression and also a reheater.

In 1852 Colladon applied for an Italian patent for the use of compressed air as a power for driving the rock drills in tunnel construction.

Jan., 15, 1854 Arthur Parsey patented in England a double acting air pump with hollow piston and rod, through which air is admitted. The valve may be as large as the cylinder. The rod passes through the valve and has a spiral spring to keep the valve seated.

In 1864 John H. Johnson took out a patent on working the piston and cylinders by compressed air, expanded by heat before entering the valve box, employing a portion of the power in forcing fresh air into the main receiver. The working piston rod carries a second piston working in an air pump and forces air into a receiver with three valves, of which one of them opens the air passage when the pressure is sufficient. The second is a safety valve, and the third is acted on by the engine govenor.

The above summary is intended to point out in a slight degree the most important steps in the development of the compressed air machinery of the present day.

THE PRODUCTION of COMPRESSED AIR.

TEST OF AN INGERSOLL SARGENT AIR COMPRESSOR

CLASS E.

The object of these tests was to determine the horse-power required to run the compressor and the efficiency of the compressor when compressing to different pressures.

To accomplish this purpose the compressor was run against pressures varying 10 lbs. at intervals of twenty-five minutes, during which time the pressure against the compressor was kept constant bt means of a hand governed valve.

The revolutions of the compressor and engine were taken at intervals of five minutes and cards were taken from the engine and compressor simultaneously

From this data the indicated horse-power of the two machines was calculated by the following formula: $\frac{P\ L\ A\ N}{33,000} = I.H.P.$ in which P means pressure of card; L, length of stroke in feet; A, effective area of piston and N number of revolutions per minute.

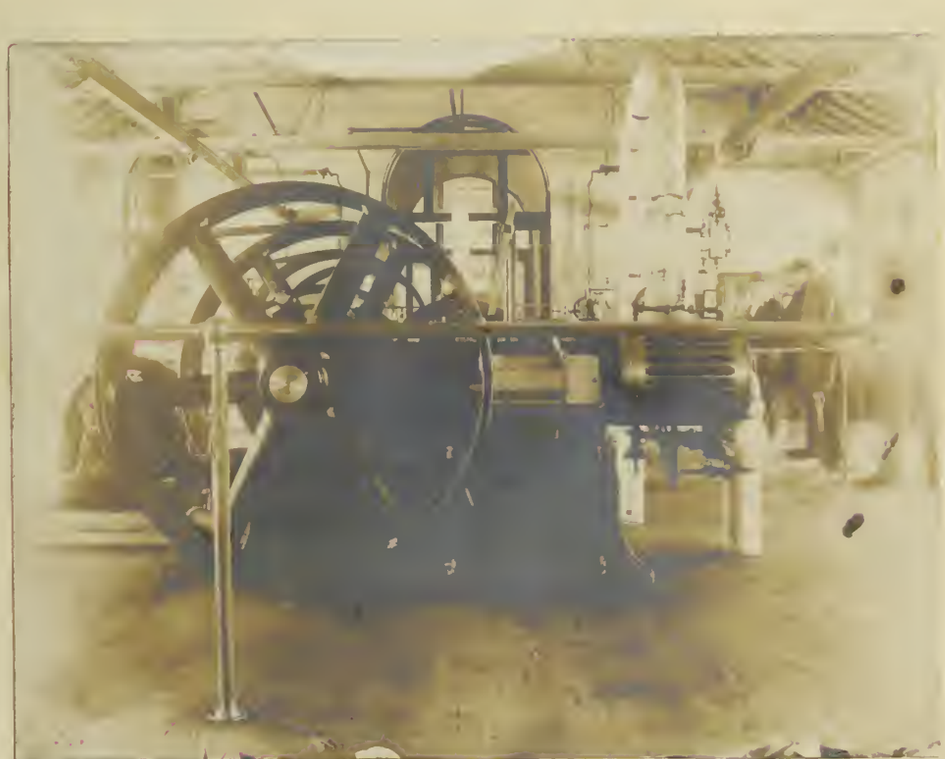
The I. H. P. was calculated for head and crank ends separately.

The constants for the 10 X 10 air compressor are for head end, $\frac{LA}{33,000} = .001983$ and for crank end, $\frac{LA}{33,000} = .001923$.

The constants for the 10 X 10 Ide engine used, are for head end, $\frac{LA}{33,000} = .001983$ and for crank end, $\frac{LA}{33,000} = .001913$.

Now, having the I. H. P. of both engine and compressor the mechanical efficiency was found by dividing the I. H. P. of the compressor by the I. H. P. of the engine.

The flow of cooling water through the water jacket of the compressor was kept constant and measured by means of a meter and found to be 61.35 cu. ft. per hr.



In order to show conditions under which test was run a thermometer was inserted in the pipe leading from compressor to tank and temperature noted at intervals of five minutes as was the temperature of room and outside air and steam pressure.

The following sheets contain the tabulated results and the orignal data showing conditions under which test was run, also characteristic cards from the engine and compressor.

T E S T N O. 1.

GEIERAL DATA.

NO.	TIME	ENGINE R.P.M.	COMP. R.P.M.	STEAM PRESS.	AIR PRESS.	EXHAUST AIR TEMP.	TEMPERATURE OUTSIDE	TEMPERATURE ROOM
1	8:00	301	151	110	0	80	21	74
2	8:05	297	150	111	"	80	21	73
3	8:10	299	151	108	"	80	22	74
4	8:15	300	152	107	"	80	23	74
5	8:20	300	152	104	"	80	24	74
6	8:25	298	151	104	10	140	23	75
7	8:30	297	150	105	"	141	23	74
8	8:35	300	152	105	"	142	23	74
9	8:40	300	151	106	"	140	24	74
10	8:45	300	151	104	"	139	24	73
11	8:50	300	151	104	20	170	23	74
12	8:55	298	150	105	"	174	24	74
13	9:00	302	152	107	"	174	24	74
14	9:05	300	151	108	"	175	27	74

NO.	TIME	ENGINE R.P.M.	COMP. R.P.M.	STEAM PRESS.	AIR PRESS.	EXHAUST AIR TEMP.	TEMPERATURE OUTSIDE	TEMPERATURE ROOM
15	9:10:	300	151	108	20	176	26	74
16	9:15:	298	150	106	30	199	27	75
17	9:20:	299	150	105	"	203	31	76
18	9:25:	299	150	108	"	204	33	76
19	9:30:	299	150	113	"	205	34	77
20	9:35:	299	150	105	"	204	35	76
21	9:40:	299	151	103	40	231	45	76
22	9:45:	299	150	108	"	232	45	76
23	9:50:	299	151	106	"	233	45	76
24	9:55:	300	151	106	"	233	45	77
25	10:00:	299	151	107	"	233	45	78
26	10:05:	299	150	106	50	252	45	77
27	10:10:	299	151	106	"	253	45	77
28	10:15:	299	150	108	"	253	45	78
29	10:20:	299	151	105	"	253	45	78
30	10:25:	299	151	103	"	254	45	77
31	10:30:	299	151	108	60	268	45	78
32	10:35:	300	151	107	"	270	45	78
33	10:40:	299	151	109	"	270	45	78
34	10:45:	299	150	109	"	271	45	78
35	10:50:	299	150	108	"	272	45	78
36	10:55:	299	150	108	70	279	45	78
37	11:00:	301	151	109	"	282	45	78
38	11:05:	299	150	108	"	282	45	78
39	11:10:	299	151	108	"	282	45	78

NO.	TIME	ENGINE R.P.M.	COMP. R.P.M.	STEAM PRESS.	AIR PRESS.	EXHAUST AIR TEMP.	TEMPERATURE OUTSIDE	TEMPERATURE ROOM
40	11:15	298	150	108	70	282	45	78
41	11:20	298	150	108	80	286	45	78
42	11:25	298	150	108	"	287	45	78
43	11:30	298	150	108	"	288	45	78
44	11:35	299	150	109	"	289	45	78
45	11:40	298	150	105	"	290	45	78
46	11:45	298	150	108	90	297	44	78
47	11:50	298	151	108	"	297	44	78
48	11:55	298	150	103	"	297	43	78
49	12:00	298	151	103	"	298	42	78
50	12:05	298	150	103	"	298	42	78
51	12:10	299	150	100	100	310	42	78
52	12:15	299	150	100	"	311	41	79
53	12:20	299	151	100	"	311	41	78
54	12:25	298	150	103	"	312	41	78
55	12:30	298	150	101	"	312	41	78

R E S U L T S.

NO.	TIME	ENGINE I.H.P.	COMP. I.H.P.	MECH. EFF. PER CENT	AVERAGE MECH. EFF. PER CENT	AIR PRESS. PER SQ. INCHES
1:	8:00:	8.36 ;				
2:	8:05:	7.82 :				

NO:	TIME	ENGINE I.H.P.	COMP. I.H.P.	MECH. EFF. PER CENT	AVERAGE MECH. EFF. PER CENT	AIR PRESS. PER SQ. INCHES
3:	8:10:	7.63 :				0
4:	8:15:	8.71 :				
5:	8:20:	7.79 :				
6:	8:25:	13.16 :	7.04 :	53.3 :		
7:	8:30:	14.49 :	6.90 :	47.6 :		
8:	8:35:	13.78 :	7.15 :	51.9 :	50.7 :	10
9:	8:40:	13.78 :	7.12 :	51.6 :		
10:	8:45:	14.42 :	7.12 :	49.3		
11:	8:50:	18.68 :	10.02 :	53.5 :		
12:	8:55:	17.11 :	10.50 :	61.3 :		
13:	9:00:	16.14 :	10.11 :	62.9 :	57.7 :	20
14:	9:05:	18.14 :	10.00 :	55.1 :		
15:	9:10:	17.89 :	10.02 :	56.0 :		
16:	9:15:	19.39 :	12.40 :	63.9 :		
17:	9:20:	19.55 :	12.27 :	62.7 :		
18:	9:25:	19.10 :	12.25 :	64.1 :	62.2 :	30
19:	9:30:	20.64 :	12.32 :	59.6 :		
20:	9:35:	19.98 :	12.20 :	61.0 :		
21:	9:40:	20.97 :	14.31 :	68.2 :		
22:	9:45:	20.99 :	14.04 :	66.8 :		
23:	9:50:	20.29 :	14.49 :	71.5 :	68.8 :	40
24:	9:55:	20.61 :	14.45 :	70.1 :		
25:	10:00:	20.93 :	14.14 :	67.5 :		
26:	10:05:	21.64 :	13.73 :	63.4 :		
27:	10:10:	23.24 :	15.17 :	65.2 :		
28:	10:15:	22.50 :	15.95 :	70.9 :	67.0 :	50

10-2-00-2M-O

BOILER PRES. 100
R. P. M. 299
SCALE 60

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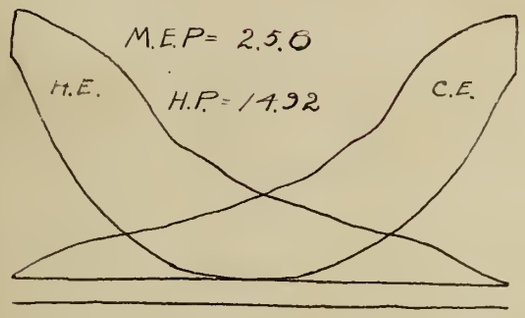
CARD NO. 51
END
CYLINDER

Crosby 2-inch Drum



A = 1.09
M.E.P = 24.6
H.P = 14.6

TOTAL H.P = 29.52

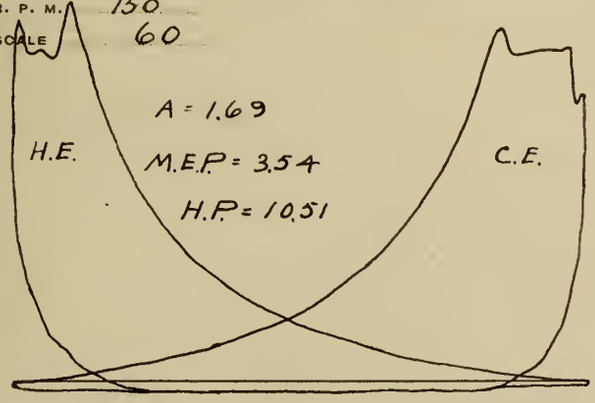
1-15-00-1M-O

~~BOILER~~ Air PRES. 100
R. P. M. 150
SCALE 60

UNIVERSITY OF ILLINOIS
MECHANICAL ENGINEERING LABORATORY

CARD NO. 51
END
CYLINDER

Thompson 1½-inch Drum



A = 1.91
M.E.P = 37.2
H.P = 10.71

TOTAL H.P = 21.22

NO	TIME	ENGINE I.H.P.	COMP. I.H.P.	MECH. EFF. PER CENT	AVERAGE MECH. EFF. PER. CENT	AIR PRESS. PER. SQ. INCHES
29	10:20	21.68	15.01	69.2		
30	10:25	22.82	15.17	66.4		
31	10:30	22.75	15.88	69.8		
32	10:35	22.75	16.77	75.2		
33	10:40	23.52	16.24	69.0	70.1	50
34	10:45	22.54	15.77	69.9		
35	10:50	23.63	15.78	66.8		
36	10:55	26.64	17.89	67.1		
37	11:00	24.77	15.78	63.3		
38	11:05	25.57	16.12	63.0	66.3	70
39	11:10	26.08	17.14	65.7		
40	11:15	23.76	17.12	72.0		
41	11:20	25.99	17.35	66.7		
42	11:25	23.41	18.23	77.8		
43	11:30	23.37	17.53	75.0	75.4	80
44	11:35	26.92	18.39	68.3		
45	11:40	26.76	18.58	69.4		
46	11:45	28.70	20.17	70.3		
47	11:50	27.35	20.31	74.2		
48	11:55	26.31	18.80	71.4	70.2	90
49	12:00	27.35	18.35	67.1		
50	12:05	27.54	18.77	68.1		
51	12:10	29.52	21.22	71.8		
52	12:15	29.52	20.52	69.5		
53	12:20	29.35	21.22	72.3	71.7	100
54	12:25	29.70	21.86	73.6		
55	12:30	30.01	21.50	71.6		

NOTE: TEST NO. 1 having been completed the clearance was unequal as shown by cards. This having been adjusted by means of lengthening the piston rod until correct position was obtained as shown by testing with indicator.

Test No. 2 was then run with the following results.

T E S T N O. 2.

GENERAL DATA.

NO:	TIME:	ENGINE: R.P.M.	COMP. R.P.M.	STEAM PRESS.	AIR PRESS.	EXHAUST AIR TEMP.	TEMPERATURE OUTSIDE	TEMPERATURE ROOM	EXHAUST WATER TEMP.
1:	8:20:	302	153	111	0	90	26	72	56
2:	8:25:	299	151.5	109	"	86	"	"	56
3:	8:30:	301	152.5	109	"	87	"	"	55.8
4:	8:35:	301	152	108	"	86	"	72.5:	55.5
5:	8:40:	301	144	109	"	84	"	"	55.5
6:	8:45:	299	151	110	10	141.5	26	72	55.5
7:	8:50:	301	152	110	"	146	"	"	56
8:	8:55:	299	150	110	"	144	"	"	"
9:	9:00:	299.5:	151.5:	110	"	143	27	72.5:	"
10:	9:05:	301	152	111	"	142	"	"	"
11:	9:10:	298	151	110	20	172	"	"	"
12:	9:15:	299	150	110	"	178	"	"	"
13:	9:20:	301	152	110	"	178	"	73	"
14:	9:25:	298	151	110	"	180	"	74	"
15:	9:30:	299	150.5:	110	"	180	"	"	"
16:	9:35:	298.5:	151	110	30	200	28	"	56.5
17:	9:40:	299	150.5:	107	"	204	"	"	56.75
18:	9:45:	298	151	105	"	206	"	"	57
19:	9:50:	298	150.5:	110	"	208	"	"	"
20:	9:55:	299	151	109	"	210	"	"	"
21:	10:00:	298.5:	150.5:	110	40	221	28	75	57
22:	10:05:	298	150	110	"	224	"	"	"

NO	TIME	ENGINE R.P.M.	COMP. R.P.M.	STEAM PRESS	AIR PRESS	EXHAUST AIR TEMP.	TEMPERATURE OUTSIDE	TEMPERATURE ROOM	EXHAUST WATER TEMP.
23	10:10	299	150	107	40	225	28	75	57.25
24	10:15	298	150.5	109	"	226	"	"	57.5
25	10:20	298.5	151	110	"	227	"	"	57.5
26	10:25	297	149.5	108	50	244	"	76	58
27	10:30	279.5	150	110	"	249	"	"	58.25
28	10:35	298	150	102	"	250	"	"	58.25
29	10:40	298	150.5	110	"	252	"	"	58.5
30	10:45	299	149.5	110	"	252	"	"	58.5
31	10:50	300	151	110.5	60	262	"	"	58.75
32	10:55	301	151	110	"	267	"	"	58.75
33	11:00	298.5	150	"	"	267	"	"	58.75
34	11:05	298	150	"	" "	270	"	"	59
35	11:10	298.5	150	"	"	270	"	"	59
36	11:15	297	149.5	"	70	275	"	77	59.5
37	11:20	298	150	"	"	275	"	"	59.5
38	11:25	299	151	"	"	280	"	"	59.5
39	11:30	297	149	"	"	280	29	78	60
40	11:35	300	151	"	"	280	"	"	60
41	11:40	298	150	"	80	286	"	"	60.5
42	11:45	297	149	"	"	288	"	"	60.5
43	11:50	297	149	"	"	290	"	"	60.5
44	11:55	298	151	"	"	290	"	"	61.0
45	12:00	296	149	"	"	292	"	"	61.5
46	12:05	298	150	"	90	302	"	"	62.0
47	12:10	297	149	"	"	304	"	"	61.5
48	12:15	297	149	107	"	304	"	"	61.5

NO:	TIME:	ENGINE: R.P.M.	COMP.: R.P.M.	STEAM: PRESS	AIR: PRESS	EXHAUST AIR TEMP.	TEMPERATURE OUTSIDE	TEMPERATURE ROOM	EXHAUST WATER TEMP.
49:	12:20:	297	149	107	90	303	29	78	61.0
50:	12:25:	297.5	149	108	"	304	"	"	61.5
51:	12:30:	297.5	150	109	100	305	30	"	61.0
52:	12:35:	297	149	107	"	408	"	"	61.5
53:	12:40:	299	151	107	"	310	"	"	62.0
54:	12:45:	297	149	108	"	311	"	"	61.5
55:	12.50:	298.5	150	108	"	312	"	"	61.5

R E S U L T S.

NO	TIME	ENGINE: I.H.P.	COMP. I.H.P.	MECH. EFF. PER CENT	AVERAGE MECH. EFF. PER. CENT	AIR PRESS. PER. SQ. INCHES
1	8:20:	10.2				
2	8:25:	8.4				
3	8:30:	9.3				0
4	8:35:	9.4				
5	8:40:	9.9				
6	8:45:	16.1	6.71:	41.6		
7	8:50:	16.2	6.61:	40.8		
8	8:55:	15.6	6.65:	42.6	43.9	10
9	9:00:	14.9	6.75:	45.3		
10	9:05:	15.4	6.87:	44.6		
11	9:10:	17.2	9.01:	52.3		
12	9:15:	17.2	8.87:	51.5		

NO	TIME	ENGINE I.H.P.	COMP. I.H.P.	MECH. EFF. PER CENT	AVERAGE MECH. EFF. PER. CENT	AIR PRESS. PER. SQ. INCHES
13	9:20	17.6	8.88	50.4	51.9	20
14	9:25	16.9	9.42	55.7		
16	9:30	17.4	8.68	50.0		
16	9:35	18.6	10.82	58.2		
17	9:40	19.6	10.97	54.8		
18	9:45	18.9	10.82	57.1	55.8	30
19	9:50	19.4	10.82	55.4		
20	9:55	19.3	10.74	55.7		
21	10:00	21.4	12.27	57.3		
22	10:05	20.3	12.15	59.8		
23	10:10	20.8	12.55	60.3	59.0	40
24	10:15	20.3	12.30	60.6		
25	10:20	21.4	12.28	57.3		
26	10:25	22.6	13.78	58.3		
27	10:30	22.7	13.44	59.2		
28	10:35	23.3	13.64	58.5	60.3	50
29	10:40	21.8	13.72	62.9		
30	10:45	22.3	14.04	62.9		
31	10:50	24.5	14.62	61.0		
32	10:55	24.5	14.46	59.0		
33	11:00	23.2	14.87	64.1	61.8	60
34	11:05	23.9	14.65	61.3		
35	11:10	23.2	14.82	63.8		
36	11:15	24.9	17.45	70.0		
37	11:20	24.2	17.17	70.9		
38	11:25	25.4	17.25	67.9	68.7	70

10-2-00-2M-O

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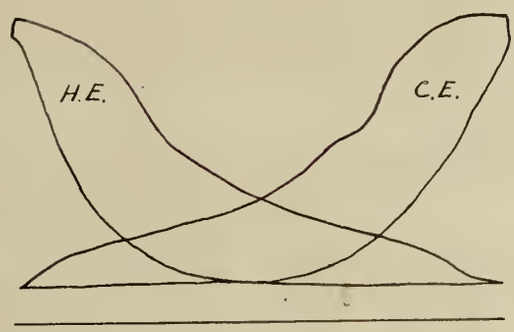
BOILER PRES. 109
R. P. M. 297.5
SCALE 60

CARD NO. 51
END
CYLINDER

Crosby 2-inch Drum

A = 1.04
M.E.P. = 23.78
H.P. = 14.0



A = 1.02
M.E.P. = 23.31
H.P. = 13.3

TOTAL H.P. = 27.3

1-15-00-1M-O

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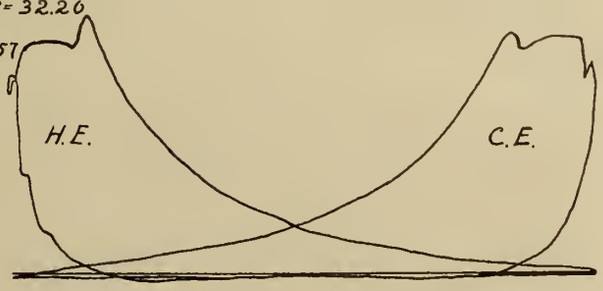
BOILER PRES. ~~Air~~ 100
R. P. M. 150
SCALE 80

CARD NO. 51
END
CYLINDER

Thompson 1½-inch Drum

A = 1.26
M.E.P. = 32.26
H.P. = 9.57



A = 1.30
M.E.P. = 33.76
H.P. = 9.73

TOTAL H.P. = 19.30

NO	TIME	ENGINE I.H.P.	COMP. I.H.P.	MECH. EFF. PER CENT	AVERAGE MECH. EFF. PER CENT	AIR PRESSURE PER SQ. INCHES
39	11:30	23.9	16.73	70.0		
40	11:35	25.1	16.31	65.0		
41	11:40	25.9	17.22	66.4		
42	11:45	27.6	16.52	59.8		
43	11:50	26.4	17.44	66.0	63.7	80
44	11:55	25.8	17.90	69.4		
45	12:00	25.7	16.17	62.9		
46	12:05	27.9	18.32	65.6		
47	12:10	27.8	18.16	65.3		
48	12:15	28.8	17.35	60.2	63.7	90
49	12:20	27.7	17.96	64.8		
50	12:25	26.9	16.86	62.6		
51	12:30	27.3	19.30	70.7		
52	12:35	27.8	19.10	68.7		
53	12:40	27.3	18.50	67.8	68.1	100
54	12:45	27.1	20.00	73.8		
55	12:50	30.3	18.13	59.8		

NOTE: On test No.2 the head end card was found to be defective so the exhaust valves were examined and the regulating by-pass was closed and test No.3 was conducted with satisfactory results.

T E S T N O. 3.

GENERAL DATA.

NO:	TIME:	ENGINE R.P.M.:	COMP. R.P.M. :	AIR PRESS:	STEAM PRESS:	EXHAUST AIR TEMP. :	TEMPERATURE OUTSIDE:	TEMPERATURE ROOM:	COOLING WATER TEMP.
1:	8:00:	300 :	152 :	0 :	110 :	90 :	39 :	78 :	55
2:	8:05:	299 :	" :	0 :	108 :	88 :	" :	77 :	"
3:	8:10:	300 :	" :	0 :	106 :	87 :	" :	" :	"
4:	8:15:	300 :	" :	" :	108 :	85 :	" :	" :	"
5:	8:20:	300 :	153 :	0 :	106 :	138 :	" :	" :	"
6:	8:25:	298 :	151 :	10 :	105 :	140 :	38 :	78 :	"
7:	8:30:	300 :	153 :	" :	107 :	142 :	38 :	" :	"
8:	8:35:	300 :	153 :	" :	110 :	140 :	37 :	79 :	"
9:	8:40:	301 :	153 :	" :	108 :	140 :	36 :	" :	"
10:	8:45:	301 :	152 :	" :	110 :	140 :	36 :	" :	"
11:	8:50:	300 :	152 :	20 :	108 :	172 :	36 :	" :	"
12:	8:55:	300 :	152 :	" :	105 :	178 :	36 :	" :	"
13:	9:00:	300 :	151 :	" :	105 :	179 :	35 :	80 :	"
14:	9:05:	300 :	151 :	" :	108 :	180 :	" :	" :	"
15:	9:10:	300 :	152 :	" :	110 :	180 :	" :	" :	"
16:	9:15:	299 :	151 :	30 :	110 :	198 :	" :	" :	55.5
17:	9:20:	" :	151 :	" :	114 :	202 :	" :	" :	56
18:	9:25:	" :	151 :	" :	113 :	204 :	34 :	" :	"
19:	9:30:	298 :	150 :	" :	110 :	204 :	" :	" :	"
20:	9:35:	299 :	151 :	" :	107 :	204 :	" :	" :	"
21:	9:40:	299 :	150 :	40 :	110 :	218 :	" :	" :	"

NO:	TIME:	ENGINE R.P.M.	COMP. R.P.M.	AIR PRESS	STEAM PRESS	EXHAUST AIR TEMP.	TEMPERATURE OUTSIDE	TEMPERATURE ROOM	COOLING WATER TEMP.
22:	9:45:	299	151	40	110	220	34	80	56.5
23:	9:50:	298	150	"	110	223	"	"	56.5
24:	9:55:	298	151	"	110	224	33	"	57
25:	10:00:	298	150	"	110	224	33	81	"
26:	10:05:	298	150	50	107	242	33	"	"
27:	10:10:	299	150	"	112	245	32	"	"
28:	10:15:	299	150	"	112	248	32	"	"
29:	10:20:	299	151	"	113	249	"	"	57.5
30:	10:25:	299	151	"	112	250	"	"	57.5
31:	10:30:	298	150	60	114	267	"	"	57.5
32:	10:35:	298	150	"	112	270	"	82	58.
33:	10:40:	298	149	"	112	270	"	"	"
34:	10:45:	298	150	"	114	272	"	"	"
35:	10:50:	299	150	"	115	272	"	"	"
36:	10:55:	299	150	70	115	280	"	"	"
37:	11:00:	298	149	"	111	282	"	"	"
38:	11:05:	299	"	"	110	284	31	83	"
39:	11:10:	298	"	"	108	284	31	"	58.5
40:	11:15:	298	"	"	105	284	30	"	58.5
41:	11:20:	"	150	80	105	288	30	"	58.5
42:	11:25:	298	"	"	113	292	"	"	59
43:	11:30:	"	"	"	114	293	"	"	"
44:	11:35:	"	"	"	112	293	"	"	"
45:	11:40:	"	"	"	113	294	"	"	"
46:	11:45:	299	"	90	113	298	"	"	"

NO	TIME	ENGINE R.P.M.	COMP. R.P.M.	AIR PRESS	STEAM PRESS	EXHAUST AIR TEMP.	TEMPERATUPE OUTSIDE	TEMPERATUPE ROOM	COOLING WATER TEMP.
47:	11:50:	299	150	90	112	300	29	83	59.5
48:	11:55:	"	"	"	112	302	29	"	60
49:	12:00:	"	"	"	110	302	28	"	"
50:	12:05:	"	"	"	110	304	"	"	"
51:	12:10:	"	151	100	114	310	"	"	"
52:	12:15:	"	150	"	113	312	"	"	"
53:	12:20:	"	"	"	114	314	"	"	"
54:	12:25:	"	"	"	114	314	"	"	"
55:	12:30:	"	"	"	112	314	"	"	"

R E S U L T S.

GENERAL DATA.

NO	TIME	ENGINE I.H.P.	COMP. I.H.P.	MECH. EFF. PER CENT	AVERAGE MECH. EFF. PER CENT	AIR PRESSURE PER SQ. INCHES.
1	8:00	7.10				
2	8:05	7.44				
3	8:10	6.69				0
4	8:15	7.685				
5	8:20	7.345				
6	8:25	12.25	6.66	54.4		
7	8:30	10.81	6.75	62.5		
8	8:35	12.485	6.56	52.5	56.38	10
9	8:40	12.23	6.89	56.3		

NO	TIME	ENGINE I.H.P.	COMP. I.H.P.	MECH. EFF. PER CENT	AVERAGE MECH. EFF. PER CENT	AIR PRESSURE PER SQ. INCHES.
10	8:45	11.63	6.54	56.2		
11	8:50	16.34	9.72	59.4		
12	8:55	15.325	9.51	62.1		
13	9:00	14.53	9.56	65.8	61.54	20
14	9:05	15.44	9.55	61.9		
15	9:10	16.215	9.64	59.5		
16	9.15	18.87	11.54	61.2		
17	9:20	19.13	11.69	61.2		
18	9:25	18.63	11.78	63.2	63.2	30
19	9:30	18.01	11.69	64.9		
20	9:35	17.44	11.61	65.5		
21	9:40	20.80	13.38	64.4		
22	9:45	20.66	12.94	62.7		
23	9:50	20.46	13.44	65.7	65.2	40
24	9:55	20.73	13.75	66.4		
25	10:00	20.46	13.66	66.8		
26	10:05	21.77	14.90	68.5		
27	10:10	21.78	14.16	65.1		
28	10:15	21.94	15.23	69.4	68.5	50
29	10:20	21.94	15.20	69.2		
30	10:25	21.70	15.25	70.3		
31	10:30	23.17	17.18	74.1		
32	10:35	23.80	17.33	72.8		
33	10:40	23.13	17.13	74.0	72.4	60
34	10:45	24.79	16.99	68.6		
35	10:50	23.62	17.13	72.5		

10-2-00-2M-O

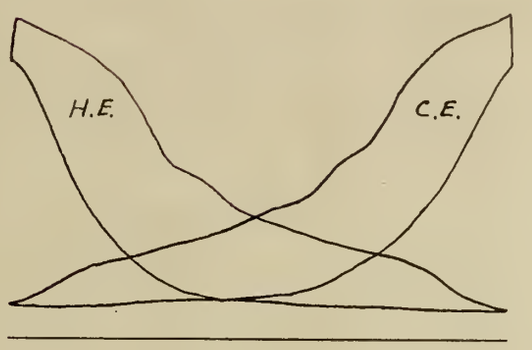
UNIVERSITY OF ILLINOIS
MECHANICAL ENGINEERING LABORATORY

BOILER PRES. 114
R. P. M. 299
SCALE 60

CARD NO. 51
END
CYLINDER

Crosby 2-inch Drum

A = 1.18
M.E.P = 27.12
H.P = 15.48



A = 1.03
M.E.P = 23.58
H.P = 13.97

TOTAL H.P = 29.45

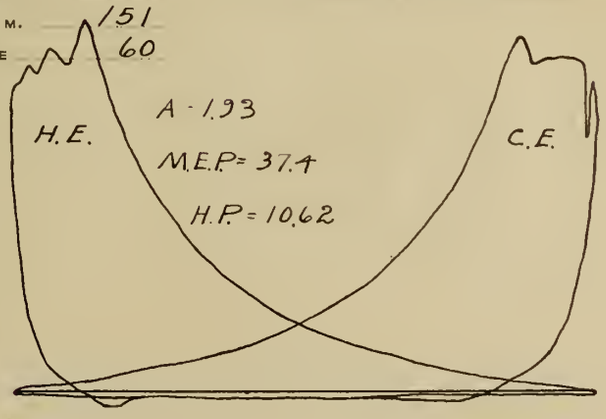
1-15-00-1M-O

UNIVERSITY OF ILLINOIS
MECHANICAL ENGINEERING LABORATORY

BOILER PRES. ~~Air~~ 100
R. P. M. 151
SCALE 60

CARD NO. 51
END
CYLINDER

Thompson 1½-inch Drum



A = 1.93
M.E.P = 37.4
H.P = 10.62

A = 1.82
M.E.P = 35.29
H.P = 10.23

TOTAL H.P = 20.85

NO	TIME	ENGINE I.H.P.	COMP. I.H.P.	MECH. EFF. PER CENT	AVERAGE MECH. EFF. PER CENT	AIR PRESSURE PER SQ. INCHES
36	10:55	26.2	18.25	69.7		
37	11:00	24.68	18.14	73.5		
38	11:05	26.45	18.02	68.2	71.48	70
39	11:10	25.63	18.02	70.3		
40	11:15	23.93	18.19	76.0		
41	11:30	26.11	19.28	73.8		
42	11:25	26.495	19.30	72.8		
43	11:30	27.13	19.22	70.8	72.74	80
44	11:35	25.77	19.22	74.6		
45	11:40	27.01	19.37	71.7		
46	11:45	26.43	20.73	78.5		
47	11:50	27.44	20.58	75.		
48	11:55	27.48	20.47	74.5	76.04	90
49	12:00	26.25	20.41	77.8		
50	12:05	27.57	20.48	74.4		
51	12:10	28.45	21.85	75.8		
52	12:15	28.61	21.20	74.1		
53	12:20	28.23	21.11	74.8	75.1	100
54	12:25	27.08	21.28	78.6		
55	12:30	27.84	21.23	76.2		

E F F I C I E N C Y T E S T

of

INGERSOLL SERGEANT DUPLEX COMPOUND AIR COMPRESSOR. CLASS H.

P. & E. Shops. Urbana, Illinois.

The object of this test was to determine the amount of power necessary to run the machine and also the efficiency with which the air compression was effected. The test was run while the machine was working under ordinary conditions. This machine supplies air for the entire shops. The test was run for three hours, from 9 A. M. until 12 M. Readings and cards were taken simultaneously every five minutes. Revolutions were recorded every minute by means of a continuous counter. The following readings were taken with each set of cards; time, steam pressure, high air pressure, low air pressure, inlet air temperature, room temperature and R. P. M.

The H. P. developed by the various cylinders was found and then the mechanical efficiency was calculated.

ENGINE CONSTANTS.

$\frac{P\ L\ A\ N}{3\ 3,\ 0\ 0\ 0} = H.\ P.$ $\qquad$ $\frac{L\ A}{3\ 3,\ 0\ 0\ 0} = \text{constant.}$

Steam Cylinders	Crank End	$\frac{la}{33,000} = .0019039$
	Head End	$\frac{la}{33,000} = .0019225$
High Pressure Air	Crank End	$\frac{la}{33,000} = .0019225$
	Head End	$\frac{la}{33,000} = .0019832$

Low Pressure Air:	Crank End	$\frac{1a}{33000}$	= .0050163
	Head End	$\frac{1a}{33000}$	= .005077

The following are the original data and results:

G E N E R A L D A T A S H E E T.

NO.	TIME	STEAM PRESSURE	AIR PRESSURE HIGH	AIR PRESSURE LOW	TEMPERATURE INLET AIR	TEMPERATURE ROOM	R. P. M.
1	9:00	75	116	26	17	83	56
2	9:05	75	115	26	17	83	55
3	9:10	78	120	27	17	83	59
4	9:15	76	120	27	18	83	44
5	9:20	75	120	27	18	83	44
6	9:25	75	110	25	19	84	56
7	9:30	73	110	26	19	84	49
8	9:35	72	105	26	19	84	50
9	9:40	75	108	26	19	84	50
10	9:45	77	115	26	19	85	47
11	9:50	78	120	27	19	86	55
12	9:55	78	125	27	19	86	49
13	10:00	78	128	27	19	86	48
14	10:05	75	130	27	19	86	43
15	10:10	75	120	27	19	88	50
16	10:15	75	125	27	19	88	52
17	10:20	72	115	27	19	84	45
18	10:25	73	118	27	19	82	49

NO.	TIME	STEAM PRESSURE.	AIR PRESSURE HIGH	AIR PRESSURE LOW	TEMPERATURE INLET AIR	TEMPERATURE ROOM	R. P. M.
19	10:30	70	115	27	20	81	44
20	10:35	72	112	27	20	81	55
21	10:40	78	117	27	20	81	67
22	10:45	75	120	27	20	79	47
23	10:50	74	115	27	20	80	63
24	10:55	75	125	27	20	79	51
25	11:00	75	127	27	20	79	42
26	11:05	81	130	27	21	81	60
27	11:10	81	140	28	21	80	54
28	11:15	76	132	27	21	79	45
29	11:20	74	118	27	22	76	51
30	11:25	78	130	27	22	78	54
31	11:30	76	133	28	22	77	44
32	11:35	78	135	28	22	80	46
33	11:40	78	133	27	22	81	53
34	11:45	72	125	28	24	80	41
35	11:50	76	122	27	26	81	56
36	11:55	76	130	27	28	82	50
37	12:00	78	135	28	28	80	49

Heat Produced by the Compression of Air.

Atmospheres.	Pounds per sq. in. above a vacuum.	Pounds per sq. in. above atmosphere gage pressure.	Volume in cu. ft.	Temperature of air throughout the process, degrees F.	Total increase of temperature degrees F.
	Pressure	*Pressure*			
1.00	14.7	0.00	1,000	60.0	00.0
1.10	16.17	1.47	.9346	74.6	14.6
1.25	18.37	3.67	.8536	94.8	34.8
1.50	22.05	7.35	.7501	124.9	64.9
1.75	25.81	11.11	.6724	151.6	91.6
2.00	29.40	14.70	.6117	175.6	115.8
2.50	36.70	22.00	.5221	218.3	158.3
3.00	44.10	29.40	.4588	255.1	195.1
3.50	51.40	36.70	.4113	287.8	227.8
4.00	58.80	44.10	.3741	317.4	257.4
5.00	73.50	58.80	.3194	369.4	309.4
6.00	88.20	73.50	.2806	414.5	354.5
7.00	102.90	88.20	.2516	454.5	394.5
8.00	117.60	102.90	.2288	490.6	430.6
9.00	132.30	117.60	.2105	523.7	463.4
10.00	147.00	132.30	.1953	554.0	494.0
15.00	220.50	205.80	.1465	681.0	621.0
20.00	294.00	279.30	.1195	781.0	721.0
25.00	367.50	352.80	.1020	864.0	804.0

Increased Efficiency Resulting from Stage Compression.
"Compressed Air."

Gauge Pressures.	One Stage.		Two Stage.		Four Stage.	
	% of work lost in terms of Isothermal Compression.	% of work lost in terms of Adiabatic Compression.	% of work lost in terms of Isothermal Compression.	% of work lost in terms of Adiabatic Compression.	% of work lost in terms of Isothermal Compression.	% of work lost in terms of Adiabatic Compression.
60	30. %	23. %	13.38%	11.8 %	4.65%	4.45%
80	34.	25.26	15.12	13.12	5.04	4.80
100	38.	27.58	17.10	14.62	8.00	7.41
200	52.35	34.40	23.20	18.88	9.01	8.27
400	68.60	40.75	29.70	22.90	12.40	11.04
600	83.75	44.60	32.65	24.60	15.06	13.10
800	90.	47.40	35.80	26.33	16.74	14.32
1000	96.80	49.20	39.00	28.10	16.90	14.45
1200	106.15	51.60	40.00	28.60	17.45	14.85
1400	108.	52.	41.60	29.4	17.70	15.00
1600	110.	53.3	42.90	30.0	18.40	15.54
1800	116.80	54.	44.40	30.6	19.12	16.05
2000	121.70	54.8	44.60	30.8	20.09	6.65

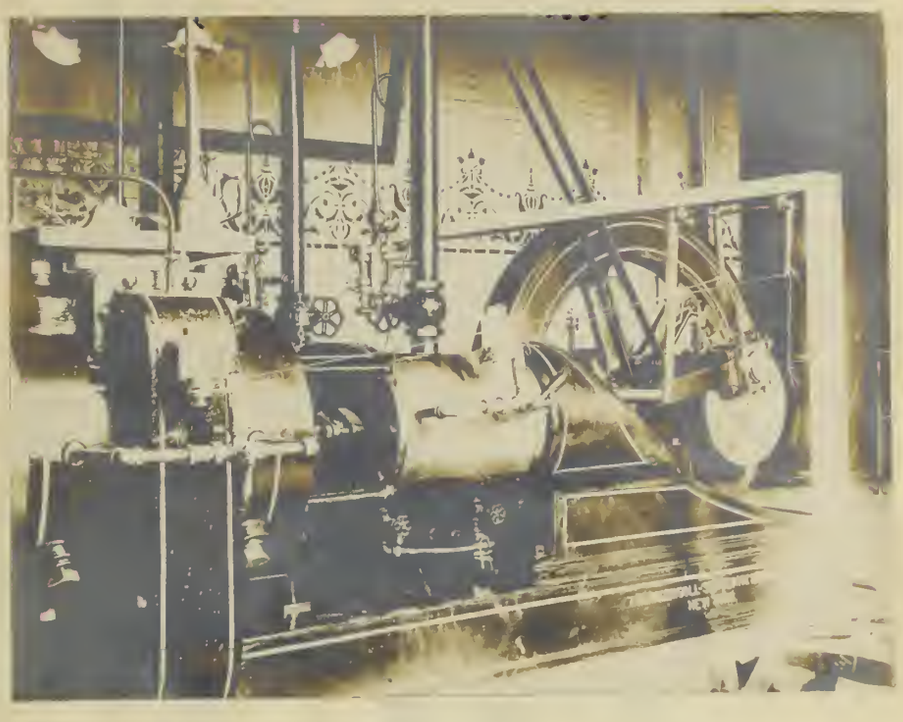
HORSE POWER DEVELOPED TO COMPRESS 100 CUBIC FEET OF FREE AIR, FROM ATMOSPHERE TO VARIOUS PRESSURES.

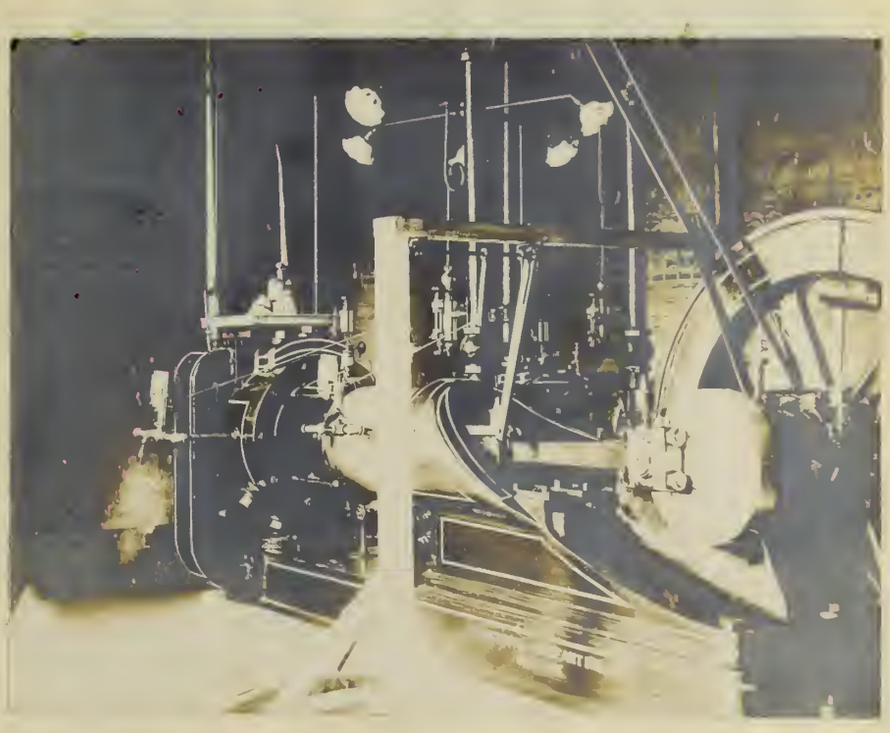
Gauge Pressure Pounds.	One-Stage Compression D. H. P.	Gauge Pressure Pounds.	Two Stage Compression D. H. P.	Four Stage Compression D. H. P.
10	3.60	60	11.70	10.80
15	5.03	80	13.70	12.50
20	6.28	100	15.40	14.20
25	7.42	200	21.20	18.75
30	8.47	300	24.50	21.80
35	9.42	400	27.70	24.00
40	10.30	500	29.75	25.90
45	11.14	600	31.70	27.50
50	11.90	700	33.50	28.90
55	12.67	800	34.90	30.00
60	13.41	900	36.30	31.00
70	14.72	1000	37.80	31.80
80	15.94	1200	39.70	33.30
90	17.06	1600	43.00	35 65
100	18.15	2000	45.50	37.80
		2500		39.06
		3000		40.15

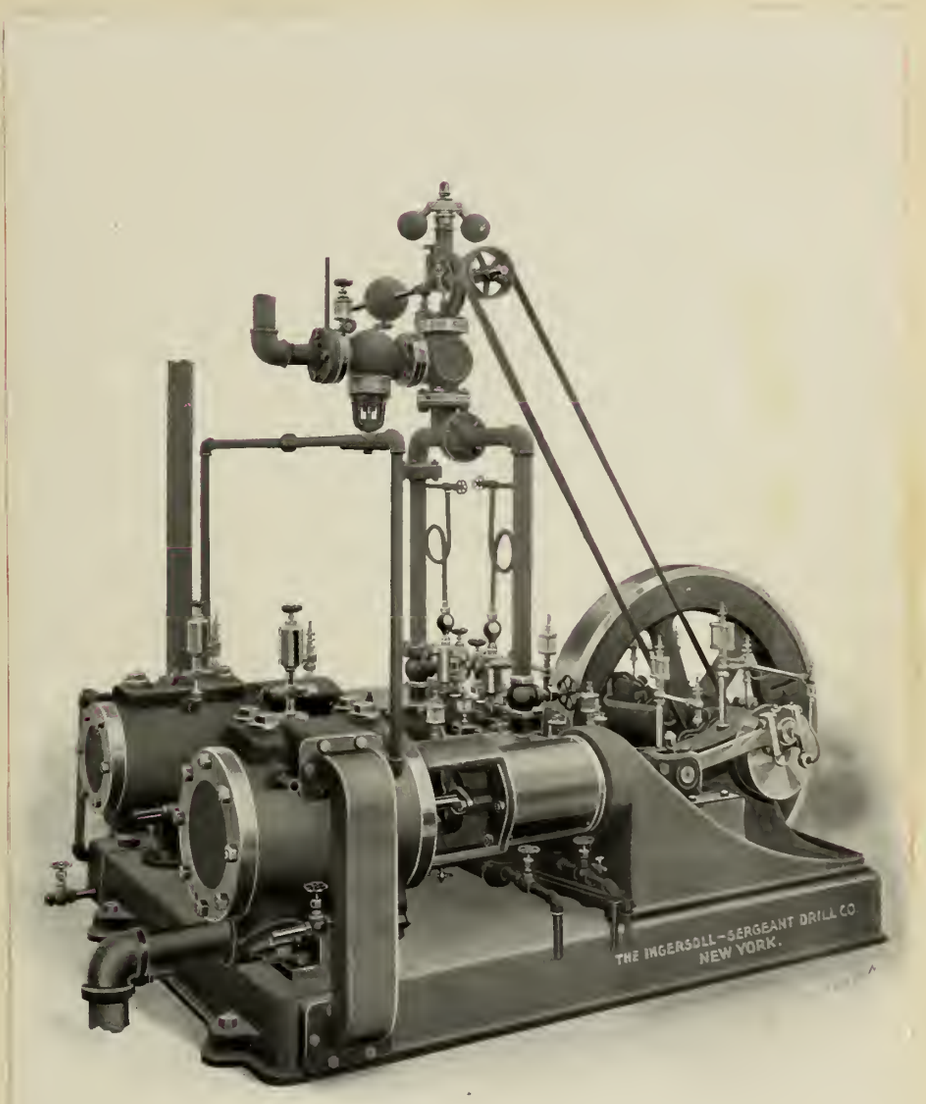
Table Showing Cubic Feet of Free Air Required to Run from One to Forty Machines with 60 lbs. Pressure.

For 75 lbs. Pressure add 1-5th.

	ROCK DRILLS.								COAL CUTTERS.	
No. of Machines.	A 2 inch.	B 2½ inch.	C 2¾ inch	D 3 inch.	E 3¼ inch.	F 3½ inch.	G 4¼ inch.	H 5 inch.	3½ inch.	4 inch.
1	65	70	95	110	115	125	140	165	70	93
2	110	120	160	190	200	230	250	280	140	186
3	156	174	234	279	294	333	360	405	210	279
4	196	220	304	356	372	428	460	524	280	372
5	230	260	370	425	445	510	555	635	350	465
6	264	294	426	486	516	588	642	738	420	558
7	294	329	476	546	581	658	721	826	490	651
8	320	360	520	600	640	720	800	920	560	744
9	360	405	585	675	720	810	900	1035	630	837
10	400	450	650	750	800	900	1000	1150	700	930
12	480	540	780	900	960	1080	1200	1380	840	1116
15		675	975	1125	1200	1350	1500	1725	1050	1395
20			1300	1500	1600	1800	2000	2300	1400	1860
25			1625	1875	2000	2250	2500	2775	1750	2325
30			1950	2250	2400	2700	3000	3450	2100	2790
40			2600	3000	3200	3600	4000	4600	2800	3720







INGERSOLL-SERGEANT DUPLEX STEAM DRIVEN AIR COMPRESSOR, CLASS "H."

With compound air cylinders and inter-cooler in base.

R E V O L U T I O N S

by

C O N T I N U O U S C O U N T E R.

TIME	R. P. M.	TIME	R. P. M.	TIME	R. P. M.
9:00	56	9:20	44	9:40	50
9:01	56	9:21	46	9:41	50
9:02	57	9:22	51	9:42	47
9:03	54	9:23	57	9:43	44
9:04	55	9:24	57	9:44	43
9:06	58	9:25	56	9:45	47
9:07	57	9:26	56	9:46	51
9:08	63	9:27	51	9:47	53
9:09	61	9:28	50	9:48	54
9:10	59	9:29	50	9:49	57
9:11	53	9:30	49	9:50	55
9:12	51	9:31	45	9:51	53
9:13	46	9:32	41	9:52	49
9:14	44	9:33	42	9:53	49
9:15	44	9:34	44	9:54	49
9:16	46	9:35	50	9:55	49
9:17	47	9:36	50	9:56	48
9:18	49	9:37	52	9:57	46
9:19	43	9:38 9:39	49 50	9:58 9:59	47 49

TIME	R. P. M.	TIME	R. P. M.	TIME	R. P. M.
10:00	48	10:26	51	10:54	52
10:01	49	10:27	52	10:55	51
10:02	46	10:28	50	10:56	48
10:03	43	10:29	48	10:57	46
10:04	43	10:30	44	10:58	42
10:05	43	10:31	45	10:59	42
10:06	49	10:32	49	11:00	42
10:07	51	10:34	55	11:01	45
10:08	52	10:35	53	11:02	45
10:09	58	10:36	53	11:03	48
10:10	50	10:37	57	11:04	53
10:11	53	10:38	62	11:05	60
10:12	55	10:39	66	11:06	64
10:13	50	10:40	67	11:07	65
10:14	51	10:41	62	11:08	64
10:15	52	10:42	65	11:09	58
10:16	52	10:43	55	11:10	54
10:17	51	10:44	56	11:11	49
10:18	50	10:45	47	11:12	48
10:19	50	10:46	52	11:13	44
10:20	45	10:47	51	11:14	43
10:21	43	10:48	51	11:15	45
10:22	44	10:49	53	11:16	51
10:23	45	10:50	63	11:17	48
10:24	46	10:51	44	11:18	50
10:25	49	10:52	52	11:19	50
		10:53	53	11:20	51

TIME	R. P. M.	TIME	R. P. M.	TIME	P. P. M.
11:21	52	11:48	53		
11:22	53	11:49	55		
11:23	51	11:50	56		
11:24	60	11:51	54		
11:25	54	11:52	53		
		11:53	48		
11:26	55	11:54	48		
11:27	51	11:55	50		
11:28	48	11:56	51		
11:29	45	11:57	53		
11:30	44	11:58	44		
11:31	47	11:59	50		
11:32	47	12:00	49		
11:33	47				
11:34	48				
11:35	46				
11:36	44				
11:37	44				
11:38	48				
11:39	52				
11:40	53				
11:41	52				
11:42	51				
11:43	47				
11:44	42				
11:45	41				
11:46	45				
11:47	48				

H O R S E P O W E R S
and
E F F I C I E N C Y.

TIME	H. P. STEAM LOW PRESS SIDE	HIGH PRESS SIDE	TOTAL H. P. STEAM	H. P. AIR LOW	HIGH	TOT L H. P. AIR	MECH. EFFIC.
1	11.38	10.77	22.15	10.50	9.44	19.94	94.2
2	11.22	10.62	21.84	10.24	9.50	19.74	90.3
3	12.08	11.33	23.46	11.29	10.29	21.58	92.0
4	8.80	8.23	17.03	8.22	7.36	15.58	91.4
5	8.82	8.32	17.14	8.01	7.23	15.24	88.9
6	10.94	10.42	21.36	10.29	9.24	19.53	91.4
7	9.70	9.11	18.81	8.27	5.68	13.95	74.1
8	9.59	9.01	18.60	9.11	7.55	16.66	89.2
9	9.80	9.27	19.07	9.08	7.77	16.85	88.3
10	9.42	9.00	18.42	8.64	7.71	16.35	88.7
11	11.27	10.67	21.94	10.07	9.46	19.53	89.0
12	10.32	9.65	19.97	10.42	8.76	19.18	86.0
13	10.06	10.89	20.95	8.98	8.35	17.33	82.7
14	8.91	8.48	17.39	7.79	7.38	15.17	87.2
15	10.34	9.73	20.07	9.46	8.74	18.20	90.6
16	10.72	11.28	22.00	10.91	9.25	20.16	91.6
17	8.90	8.45	17.35	8.35	7.23	15.58	89.8
18	8.89	9.44	19.33	9.27	8.35	17.62	90.0
19	8.88	8.22	17.10	8.14	7.26	15.40	90.0

10-2-00-2M-0

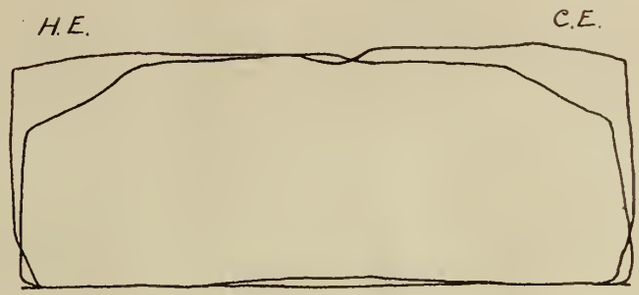
UNIVERSITY OF ILLINOIS
MECHANICAL ENGINEERING LABORATORY

BOILER PRES. .....
R. P. M. 5
SCALE 50

CARD NO. 36
END
CYLINDER

Crosby 2-inch Drum

A = 3.73
M.E.P = 56.23
H.P = 5.40



A = 3.73
M.E.P = 56.23
H.P = 5.35

TOTAL H.P = 10.75

STEAM--Low Pressure Side.

10-2-00-2M-0

UNIVERSITY OF ILLINOIS
MECHANICAL ENGINEERING LABORATORY

BOILER PRES. .....
R. P. M. .....
SCALE 50

CARD NO. 36
END
CYLINDER

Crosby 2-inch Drum

A = 3.54
M.E.P = 53.63
H.P = 5.15
H.E.

A = 3.32
M.E.P = 50.30
H.P 4.78
C.E.

TOTAL H.P = 9.93

STEAM--High Pressure Side.

10-2-00-2M-O

Air
~~BOILER~~ PRES. 27
R. P. M. 50
SCALE 30

UNIVERSITY OF ILLINOIS
MECHANICAL ENGINEERING LABORATORY

CARD NO. 36
END
CYLINDER

Crosby 2-inch Drum

A = 2.05
M.E.P = 19.40
HP = 4.92

A = 2.05
M.E.P = 19.40
H.P. = 4.86

TOTAL H.P. = 9.78

LOW PRESSURE AIR.

1-15-00-1M-O

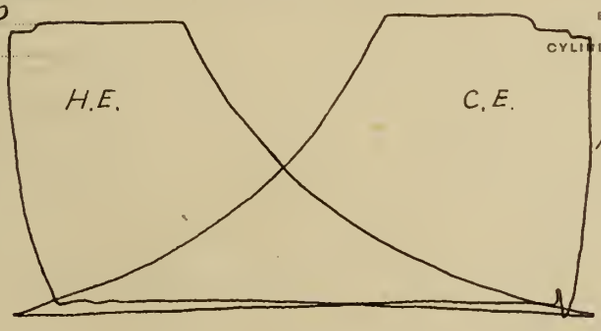
Air
BOILER PRES. 130
R. P. M. 50
SCALE 60

UNIVERSITY OF ILLINOIS
MECHANICAL ENGINEERING LABORATORY

CARD NO. 36
END
CYLINDER

Thompson 1½-inch Drum

A = 2.24
M.E.P = 43.92
H.P = 4.35



A = 2.56
M.E.P = 50.19
H.P = 4.82

TOTAL H.P = 9.17

HIGH PRESSURE AIR.

TIME	H. P. STEAM LOW PRESS SIDE	HIGH PRESS SIDE	TOTAL H. P. STEAM	H. P. AIR LOW	HIGH	TOTAL H. P. AIR	MECH. EFFIC.
20	11.27	10.67	21.94	10.37	8.98	19.35	88.2
21	13.75	13.19	26.94	12.59	11.19	23.78	89.0
22	9.83	9.27	19.10	8.84	8.05	16.89	88.4
23	12.77	12.08	24.85	11.82	10.36	22.18	89.2
24	10.78	10.20	20.98	10.64	8.96	19.60	93.4
25	8.99	8.44	17.43	7.96	7.55	15.51	88.9
26	13.02	12.55	25.57	11.15	11.01	22.26	87.0
27	12.13	11.25	23.38	10.15	10.19	20.44	87.4
28	9.73	9.04	18.77	8.48	8.29	16.77	89.3
29	10.37	9.84	20.21	9.37	8.68	18.05	89.3
30	11.71	10.81	22.52	10.22	10.08	20.30	94.6
31	9.53	8.99	18.52	8.44	8.25	16.69	90.1
32	10.07	9.63	19.71	8.57	8.40	16.97	84.1
33	11.56	10.82	22.38	11.29	10.05	21.29	95.1
34	8.74	8.05	16.79	7.72	7.15	14.87	88.5
35	11.95	11.01	22.96	10.50	9.93	20.43	88.9
36	10.75	9.93	30.68	9.78	9.17	18.95	91.6
37	10.41	10.09	20.50	9.17	9.19	18.36	89.5

T H E T R A N S M I S S I O N O F A I R

for

P N E U M A T I C T O O L S.

TESTS ON THE DISTRIBUTION OF COMPRESSED AIR through M A I N P I P E L I N E S.

(Conducted by M. Victor Popp in Paris)

LOSS of AIR.

The loss or decrease in pressure of compressed air in main pipe lines is due to either or both of the following causes. The loss in weight of air caused by leakage and the loss in pressure due to friction. Both of the above are of great importance and should be taken into consideration.

The leakage if properly attended to in due time and if the main pipe line is kept fairly tight does not require mich attention as it is the duty of and to the interest of any central compressed air power plant engineer to reduce leakage to a minimum. They remain a constant factor loss in amount of air furnished. The loss of compressed air through leakage is about proportional to the number of fittings, and it amounts to about 6% of the total capacity of the plant.

LOSS OR REDUCTION OF PRESSURE due to FRICTION IN MAIN PIPE LINE.

The reduction in pressure due to friction is a question of the greatest importance; the following will show some of the causes.

(The following tests were made by Prof. Gutermuth). All tests were run at night and on Sundays when the traffic and supply were practically steady. These tests have proved that extraordinary loss of pressure was due to short bends, principally in the smaller branch pipe line running up hill, not with standing the large diameter of 12" and the great number of receivers and automatic water traps connected with same. Thus it was decided to make a thorough test to determine the loss of pressure due to the receivers placed in pipes and then in the main and branch pipes between the receivers.

The following are the results:

PRESSURE AT ENTRANCE OF RECEIVER	PRESSURE AT OUTLET OF RECEIVER	LOSS	AVERAGE SPEED PER SECOND THROUGH PIPES
92.84 lbs.	91.87 lbs.	0.97 lbs.	19.8'
92.36 "	91.28 "	1.08 "	19.1'
71.74 "	69.23 "	2.51 "	28.7'
95.25 "	93.05 "	2.20 "	24.4'
90.11 "	89.08 "	1.03 "	18.5'

The figures show positively that for each receiver there is a loss of 15% of one atmosphere when the speed of air amounts to 23 ft. per second, and that for 30 ft. per second the loss due to friction amounts to 0.2 of one atmosphere. Twenty-three automatic water traps which were installed at different places on the main pipe line did not cause any perceiptible loss of pressure.

The following table shows the distance in miles and number of tests from which the above table of results was obtained.

MILES	TESTS	MILES	TESTS
10.28	7	2.08	3
8.15	3	1.06	2
7.50	4	0.44; 4.57	11
5.75	5	2.74	8

These experiments were made at a place situated respectively four and five miles from the central power plant and all readings were automatically registered by automatic recording pressure guages placed at convenient places. All tests were thus made on a main pipe line having a total length of nine and one half miles and fitted with four air receivers, twenty-three automatic water traps and forty - two gate valves. The resistance or loss of pressure was made under different speeds of compressed air varying from 0 to 50 ft. per sec.

(FROM COMPRESSED AIR)

FLOW OF COMPRESSED AIR IN PIPES.

(The following is an extract from an article by William Cox in Compressed air. Vol. II No. 11 & 12, Vol. III No. 1)

The volume of a fluid discharge from a pipe is very easily ascertained by means of the formula,

$$(1)\quad D = \frac{V \times 0.7854 d^2 \times 12 \times 60}{1728} = V \times d^2 \times 0.32725$$

Where D = discharge in cu. ft. per minute,

V = mean velocity of flow in ft. per second.

d = internal diameter of the pipe in inches.

A formula applicable to the flow of an elastic fluid in a pipe is the following,

$$(2)\quad V = C \sqrt{\frac{d(P' - P^2)}{W' L}}$$

Where P' = initial guage pressure in lbs. per sq. inch.

P^2 = final gauge pressure in lbs per sq. inch.

$P' - P^2$ = difference of pressures, or pressure required to

overcome friction and produce the velocity of flow, equivalent to the loss of head.

W′ = density or weight in lbs. per cu. ft. of the fluid at the initial pressure P.

L = length of pipe in feet.

V = velocity in ft. per second.

C = a variable co-efficient to be determined by experiment. If the value of V as given bu Equation ( ) is inserted in Equation (1) we obtain

$D = C\sqrt{\frac{d^5(P' - P^2)}{W' L}}$ which gives the discharge of compressed air in cu. ft. per minute from a pipe of any diameter and length, with any initial and final pressures, the volume of discharge thus obtained being under the terminal pressure P.

The above article gives tables showing the value of the coefficient under different conditions.

FLOW OF COMPRESSED AIR THROUGH LONG PIPES.

P^2 = final pressure in lbs. per sq. inch.

P′ = initial " " " " " "

V′ = initial velocity of air in ft. per. second.

L = length of pipe in ft.

D = diameter of pipe in ft.

FORMULA FOR THE FRICTION OF AIR IN PIPES.
(From Richards Compressed Air)

D = Diameter of pipe in inches.

L = Length of pipe in feet.

V = Volume of air delivered in cu. ft. per minute.

H = Head or difference of pressure required to overcome friction and maintain the flow.

$$H = \frac{V^2 L}{10000\, D_a^5} \qquad V = \sqrt{\frac{10000\, D_a^5\, H}{L}}$$

$$D_a^5 = \frac{V^2 L}{10000\, H} \qquad L = \frac{10000\, D_a^5\, H}{V^2}$$

A complete table of values for the factor A is given in the above article.

Flow of Air Through an Orifice in Cubic Feet of Free Air per Minute.

Flowing from a round hole in Receiver into the Atmosphere.

RECEIVER GAUGE PRESSURE.

Diam. of Orifice.	2 lbs.	5 lbs.	10 lbs.	15 lbs.	20 lbs.	25 lbs.	30 lbs.	35 lbs.	40 lbs.	45 lbs.	50 lbs.	60 lbs.	70 lbs.	80 lbs.	90 lbs.	100 lbs.	125 lbs.
1-64"	.038	.0597	.0842	.103	.119	.133	.156	.173	.19	.208	.225	.26	.295	.33	.364	.40	.486
1-32"	.153	.242	.342	.418	.485	.54	.632	.71	.77	.843	.914	1.05	1.19	1.33	1.47	1.61	1.97
1-16"	.647	.965	1.36	1.67	1.93	2.16	2.52	2.80	3.07	3.36	3.64	4.2	4.76	5.32	5.87	6.45	7.85
1/8"	2.435	3.86	5.45	6.65	7.7	8.6	10.	11.2	12.27	13.4	14.50	16.8	19.0	21.2	23.50	25.8	31.4
1/4"	9.74	15.40	21.8	26.70	30.8	34.5	40.	44.7	49.09	53.8	58.2	67.	76.	85.	94.	103.	125.
3/8"	21.95	34.60	49.0	60.	69.	77.	90.	100.	110.45	121.	130.	151.	171.	191.	211.	231.	282.
1/2"	39.00	61.60	87 0	107.	123.	138.	161.	179.	196.35	215.	232.	268.	304.	340.	376.	412.	502.
5/8"	61.00	96.50	136.	167.	193.	216.	252.	280.	306.80	336.	364.	420.	476.	532.	587.	645.	785.
3/4"	87.60	133.	196.	240.	277.	310.	362.	400.	441.79	482.	522.	604.	685.	765.	843.	925.	
7/8"	119.50	189.	267.	326.	378.	422.	493.	550.	601.32	658.	710.	622.	930.	1004.			
1"	156.00	247.	350.	427.	494.	550.	645.	715.	785.40	860.	930.						
1 1/4"	242.00	384.	543.	665.	770.	860.	1000.										
1 1/2"	350.00	550.	780.	960.													
2"	625.00	985.															

DEVELOPMENT OF PERCUSSIVE TOOLS.

(The following is an extract from Vol.V No.9 and Vol. VI No.1 of Compressed Air Magazine)

In the last few years the use of compressed air as a motive power for machinery has wonderfully increased, especially for portable tools. This is mainly due to the advantageous qualities of compressed air over steam, the principal of which are:

FIRST: Stability, or in other words, non condensation, permitting it to be stored indefinitely, or to be transported long distances without loss of pressure, other than that due to leakage and friction of the conduit.

SECOND: Low temperature at which it can be used in hand tools

THIRD: The exhaust consists of fresh cool air, adding to the ventilation and confort of the work room or mine.

FOURTH: It can be used at any pressure and is easily produced and its expansive qualities, which not on a par with steam, owing to the absence of heat, yet can be utilized with good results.

With these few reminders of the qualities of compressed air, the subject of its application to percussive tools comes up.

Percussive force, as regards the actual work done upon the object struck, is applied in two ways;

FIRST: Directly, when the tool itself is propelled through space and strikes the object, when practically all of the energy of the moving mass is expended on the object struck.

SECOND: Indirectly, when the moving mass strikes an inter-

posed tool, through which the energy is transferred to the object.

Examples of the first type are the hand hammer, sledge, steam hammers and rock drills.

Examples of the second type are the mason striking his stationary chisel, and the chisel struck by the piston of a pneumatic hammer.

Trip hammers of crude form were in use as early as 1600, and before them spring catapults were used to throw great stones against castle walls.

Nasmyths' steam hammer, invented in the early forties, was a great step forward. In 1844 Brunton suggested compressed air in a cylinder as a convenient means of working a hammer to hit a drill.

Oct. 15, 1851 Cave, a Frenchman, patented a compressed air rock drill.

Couch, an American, patented a rock drill in 1849.

Since that time there have been wonderful imptovements in the details and numberless devices made for regulating and controlling the different parts.

There are three methods of automatically controlling the admission of the motive fluid.

FIRST: The tappet valve type, in which projections attached to the reciprocating part, strike triggers or other devices which in turn move the valve.

SECOND: The fluid moved valve type, where in the piston itself, at certain parts of its travel, admits a supply of motive fluid to move the valve or to move a supplementary piston which in turn moves the valve.

THIRD: The so called valveless type, in which the moving piston acts as its own valve, as in its stroke, it alternately opens

and closes certain parts, so that the fluid acts on each end of the piston in turn.

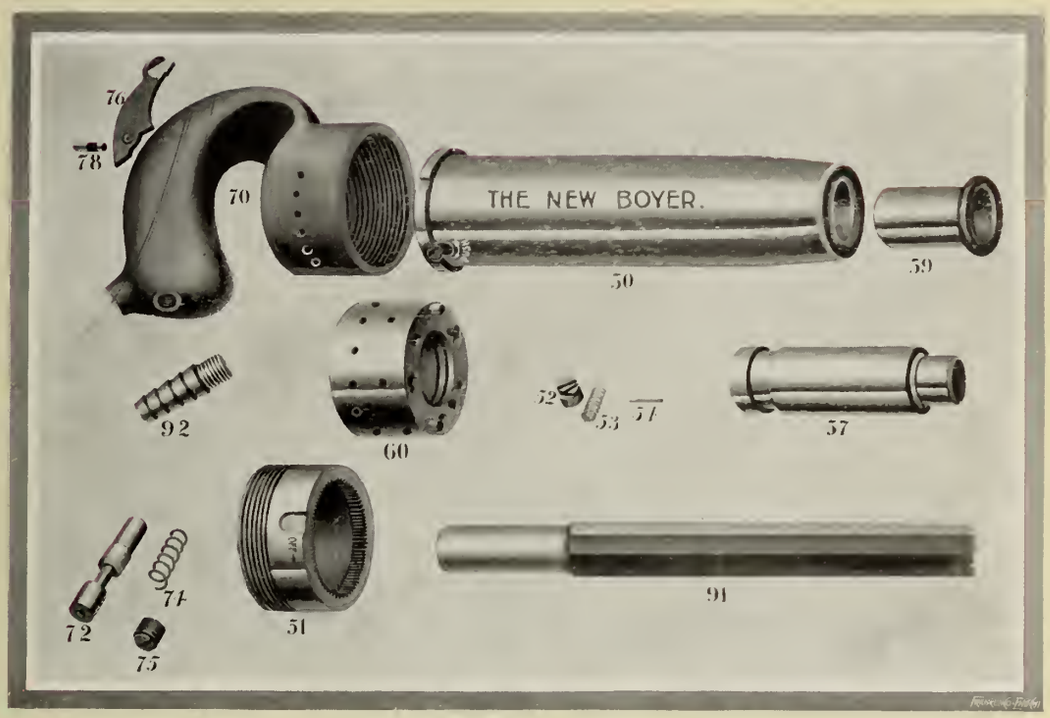
Hammers then may broadly be divided into two types, namely, the valveless hammer and the valve hammer. Of the former type the Ross, and Q. & C. are the best known.

Of the valve type, the Boyer hammer, made by the Chicago Pneumatic Tool Co., and the "Little Giant" hammer made by the Standard Pneumatic Tool Co., are the best known.

Valveless hammers have essentially a short stroke, and although economical in air consumption in relation to the number of blows given, they will not compare with valve hammers in giving powerful blows. The speed of the valveless hammers is very high, being 10,000 to 20,000 strokes per minute.

The speed of the valve hammers, for ordinary work, ranges from 1,500 to 2,000 blows per minute, although they can be driven much faster. Their stroke however, is considerably longer than that of the valveless hammers, and the blow struck correspondingly harder.

(For a complete description of construction and operation of the vaious types of hammers, see Compressed Air, Vol. VI No. I Mar. 1901.)


THE NEW BOYER.
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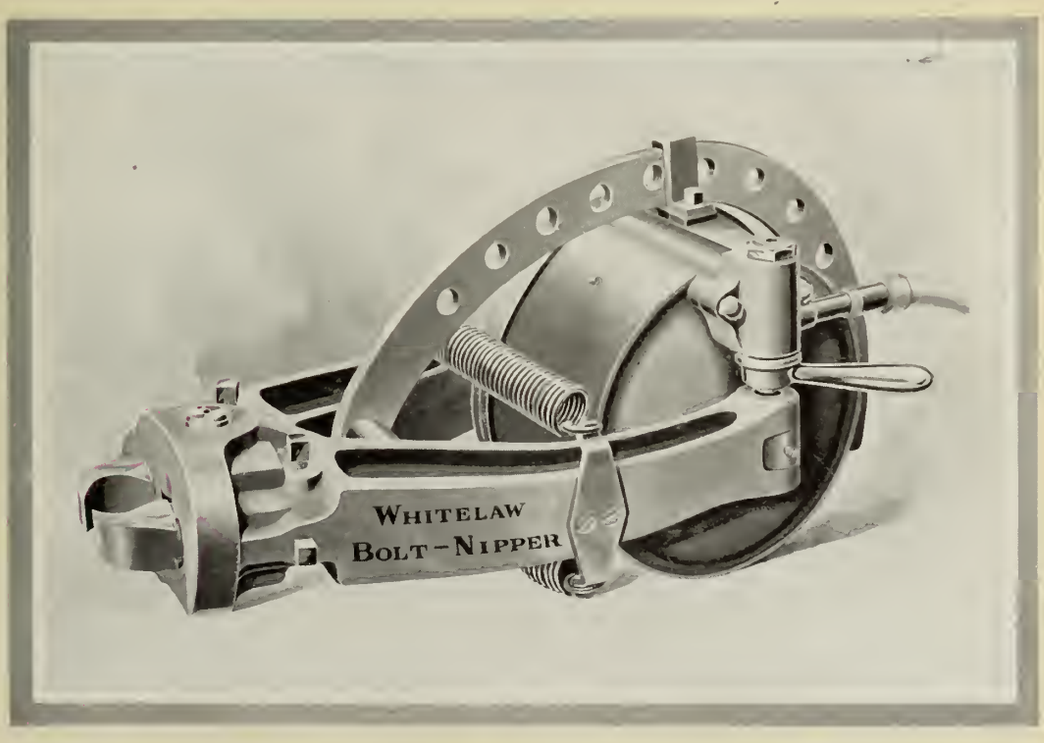
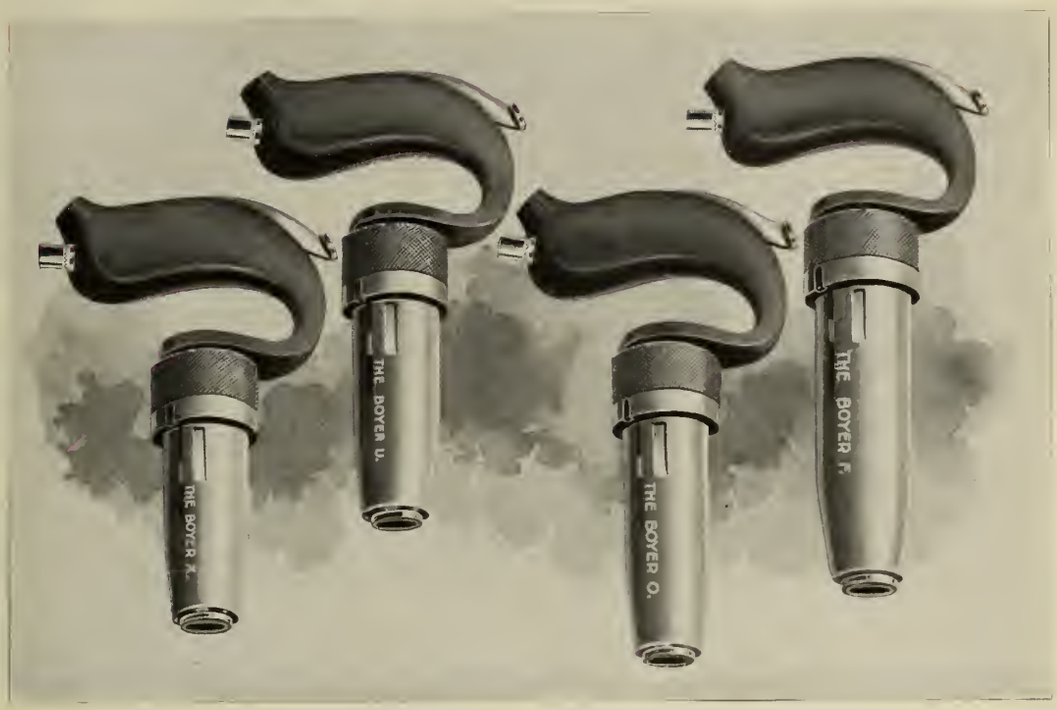
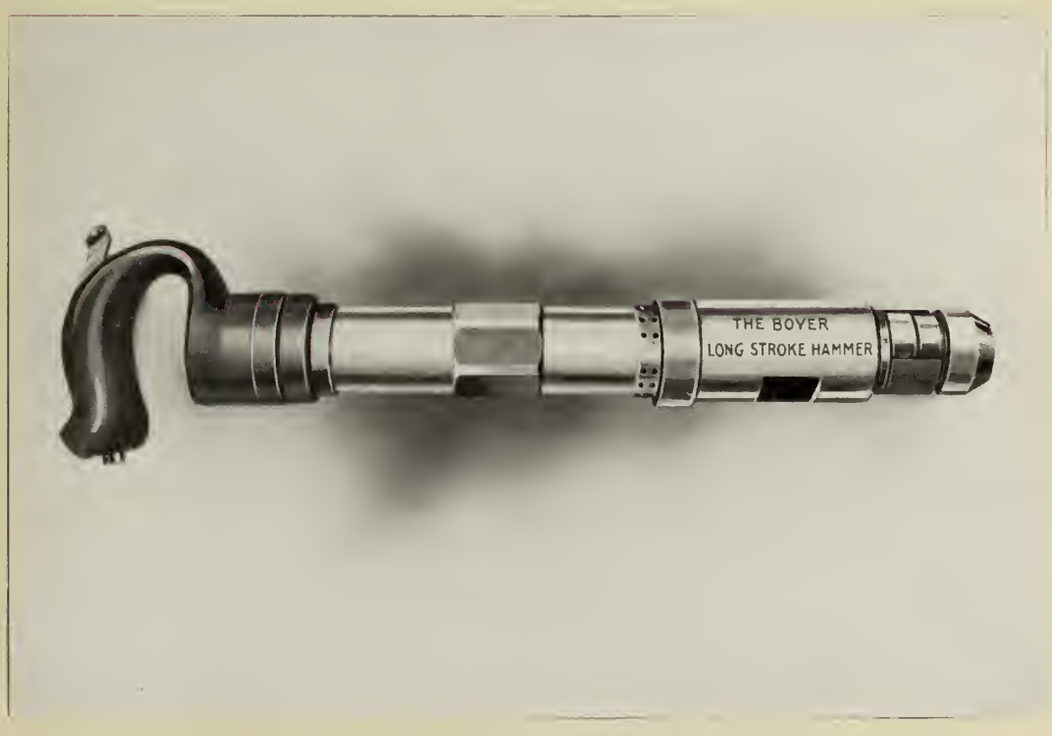
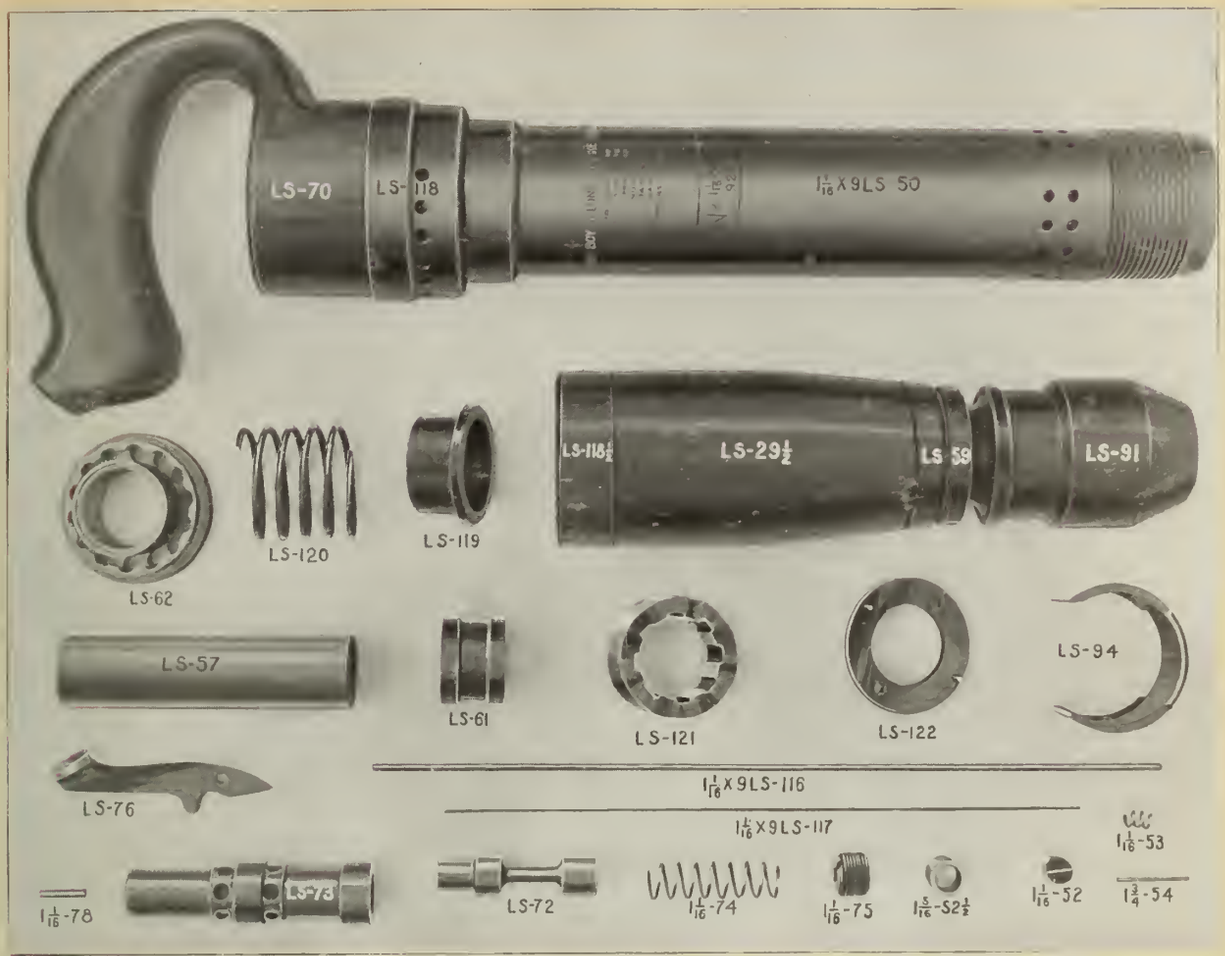
91

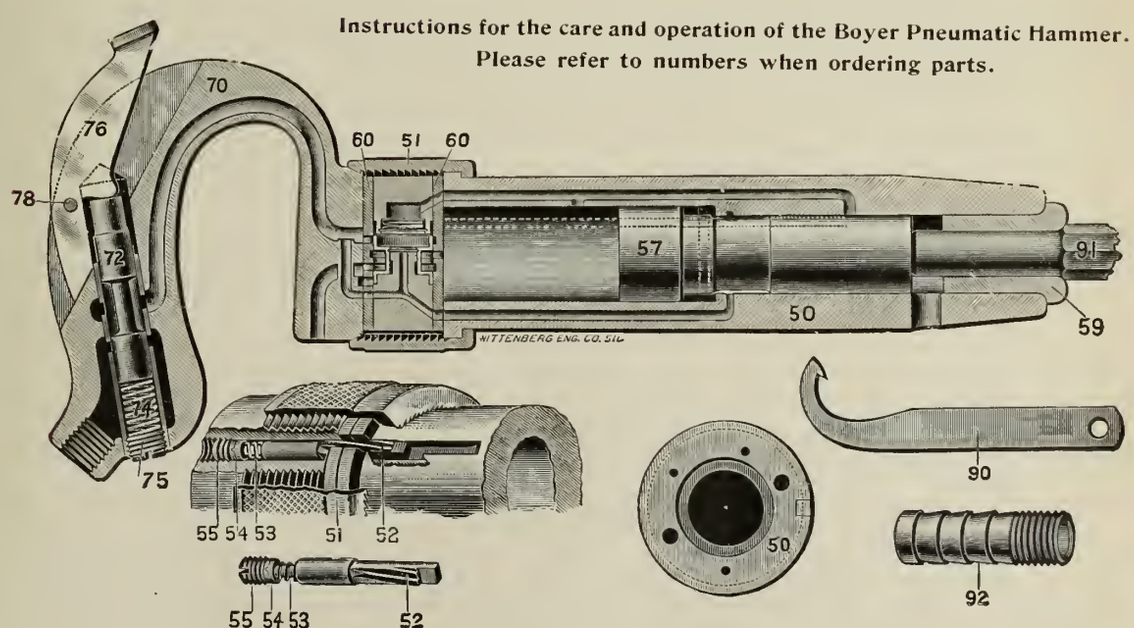

WHITELAW
BOLT-NIPPER


THE BOYER R.
THE BOYER U.
THE BOYER O.
THE BOYER F.


THE BOYER
LONG STROKE HAMMER



Instructions for the care and operation of the Boyer Pneumatic Hammer.
Please refer to numbers when ordering parts.

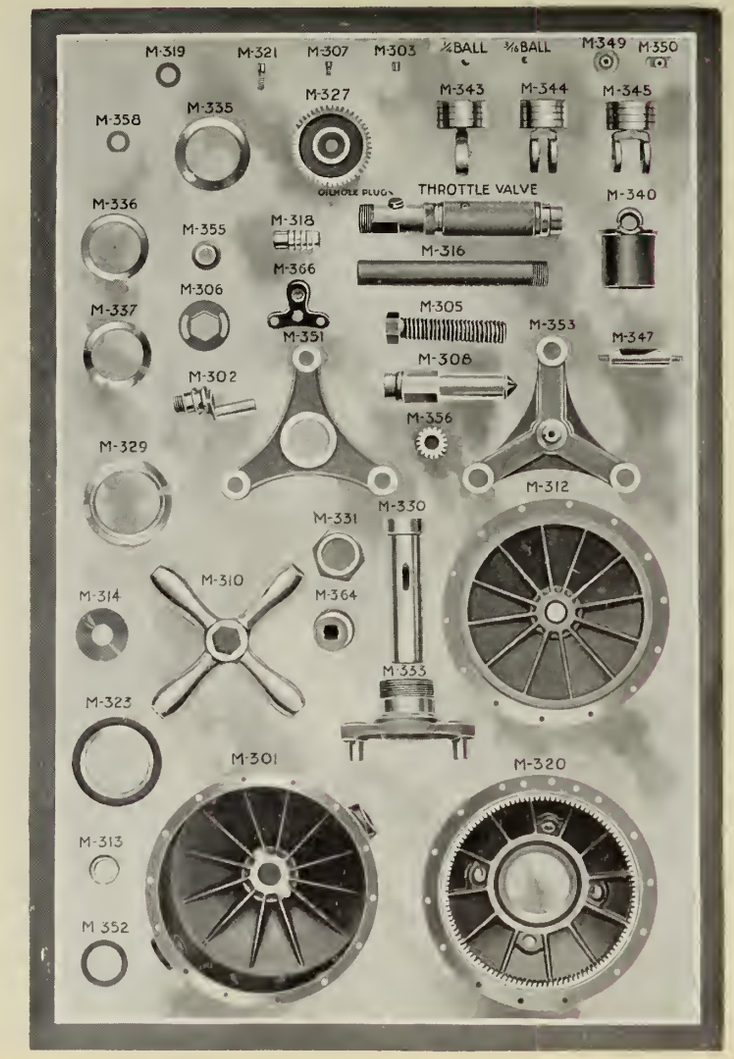


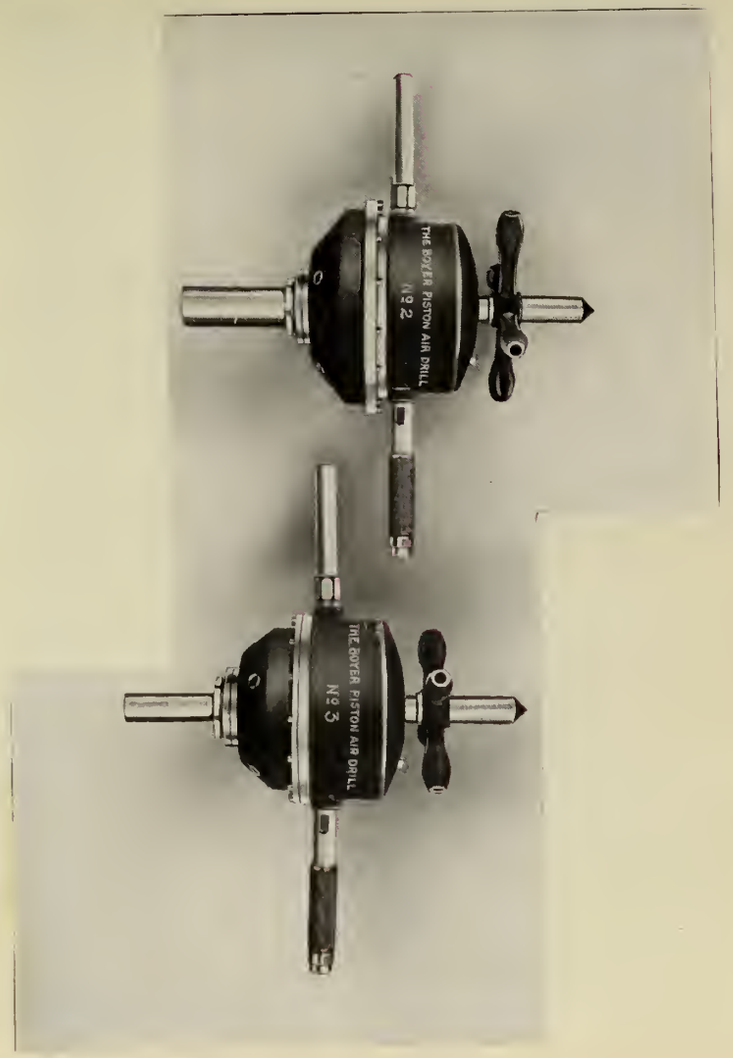
TESTS ON BOYER PISTON AIR DRILL, NUMBER, M. 31050

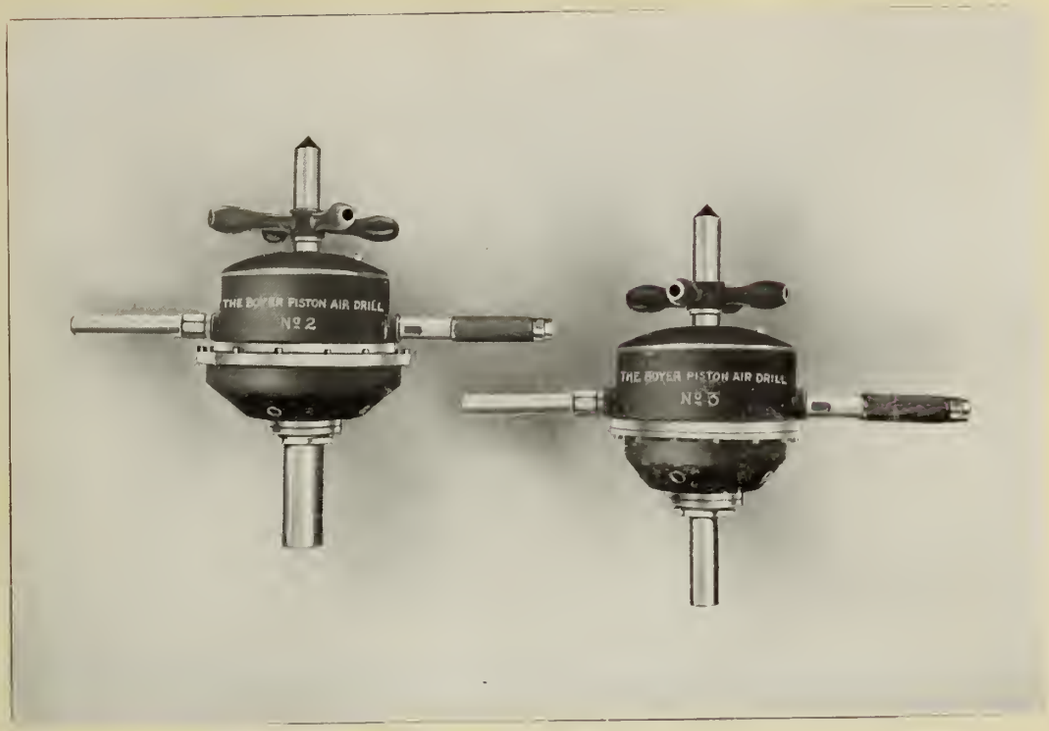
PATENTED SEPT. 21, 1897.

Description of Drill.

This machine consists of three main parts: (1) The upper housing into which the throttle valve and steadying handle are screwed, and which forms a live-air chamber carrying the motor. (2) The diaphragm which forms the lid or cover of the upper housing or live air chamber and through which the hollow exhaust spindle projects; (3) The lower housing secured to the upper housing by means of screws, and containing the gear wheel rack, bearings for drill spindle, ect. The motor is in the form of a three-cylinder single-acting oscillating engine, the cylinders being carried in the rotary frame. This frame consists of an upper and lower plate, and is triangular in shape and is free to revolve around its center on two bearings, the lower one being a hollow shaft, and connected by a gearing to an internally toothed wheel in the lower half of the casing. The admission of air to the cylinders is regulated by the valves formed in the pivots upon which the cylinders oscillate. The cylinders are single acting and the inner ends are open, and therefore air under pressure, of which the upper casing is always full, has free access to the pistons on that side. It would seem, therefore, that air being admitted through the pivot valves would only produce equilibrium, but since one of the cylinders is always open to the exhaust through the hollow bearing of the triangular frame, this equilibrium becomes disturbed, and the compressed air has full effect upon each piston as the valve comes in line with the exhaust. The cylinders are constructed of steel tubes, and are fitted with trunk pistons having


M-319
M-321
M-307
M-303
1/4 BALL
3/16 BALL
M-349
M-350
M-358
M-335
M-327
M-343
M-344
M-345
OILHOLE PLUG
THROTTLE VALVE
M-336
M-355
M-318
M-340
M-316
M-366
M-306
M-337
M-305
M-353
M-347
M-351
M-308
M-302
M-356
M-329
M-312
M-331
M-330
M-310
M-314
M-364
M-333
M-323
M-301
M-320
M-313
M 352


THE BOYER PISTON AIR DRILL
№ 2
THE BOYER PISTON AIR DRILL
№ 3


THE BOYER PISTON AIR DRILL
No 2
THE BOYER PISTON AIR DRILL
No 3

their connecting-rod ends attached to a fixed crank pin common to them all; the pistons having been set in motion by the introduction of compressed air into the upper casing, and into the cylinder as already described, has the effect of causing the three cylinders, together with their triangular framing, to rotate around the fixed crank-pin, and thus transmit rotary motion to the spindle by means of the gearing before referred to. This class of machine is fitted with a regulator by means of which the power and speed of the drill can be varied as desired.

The object of these tests was to determine the work developed and also the air consumption of the drill under various air pressures and various loads.

The pressure at the drill was held constant at any desired pressure by means of a throttle valve operated by hand. The load at all pressures was changed from zero to a maximum. The tests up to 55 lb. pressure were run with a brake of 1 ft. radius. Tests of higher pressures were run with a compound brake of 2 ft. radius. The load radius and R. P. M. being known, the work developed was calculated.

The drill was located directly in front of the receiver tank. The air was conducted, from the out-let nozzle of the receiver, to the drill, by means of a short hose. Between the throttle valve and the drill a pressure guage was located. The revolutions were obtained by a speed counter inserted in the end of the blank tool upon which the brake pulley was fastened.

THE DETERMINATION OF AIR CONSUMPTION.

The first step in this direction was the calibration of the air receiver tank. To do this the tank was tapped at the extreme top

and bottom. A valve was placed at the bottom so that all water and oil could be drawn out. All valves about the tank were now closed and water was inserted in the top. This was allowed to run until the tank overflowed. The water was then drawn out at the bottom and weighed. The cubic contents was then calculated. This determination of contents was repeated three times with the same result. The cubic contents was found to be 89.647 cubic feet. In the side of the receiver tank thermometers were placed. One about three feet from the top, the other about four feet from the bottom and also about one foot above the out-let nozzle. All valves having been closed except the inlet, the pressure was pumped up until the guage on the receiver stood near 105 lbs. Now the inlet valve was closed. Next the drill was started with the desired pressure and load. Just as the pressure in the tank fell to 100 lbs. the time was caught by means of a stop watch. The temperatures were also noted at this instant. The average of the two was taken as the real temperature of the air. The drill was run continous with pressure and load constant, until the pressure in the tank fell to that at which the drill was running. Just as this was reached the time was caught and the temperatures again noted. The average of which was taken. Now with this data we are able to calculate the air consumption, by means of the following formulae:

(1) P', V', T' (2) $P^2 V^2 T^2$

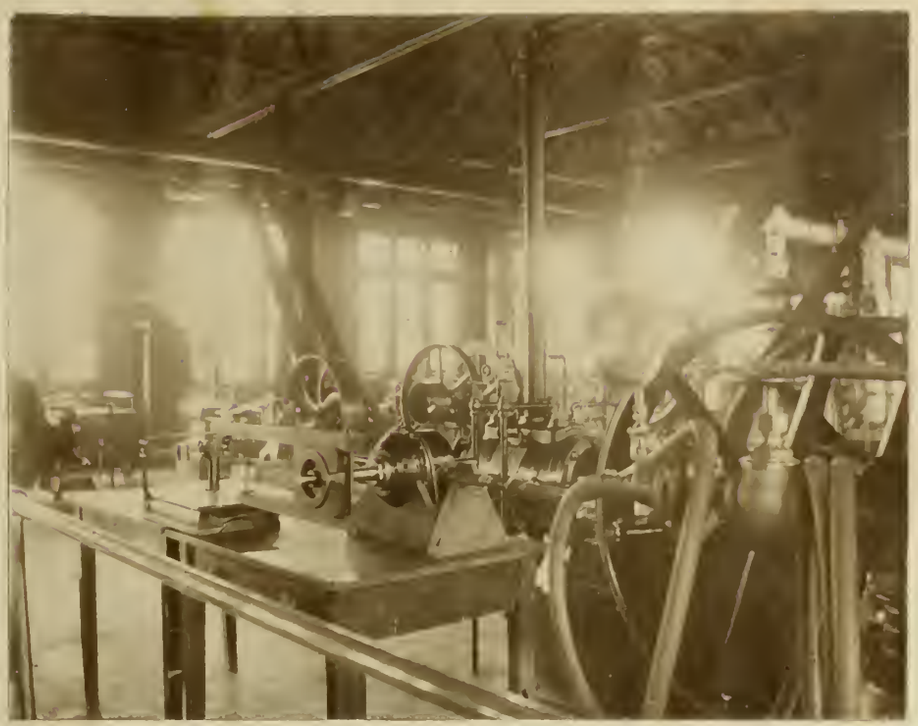
$$\frac{P_1 V_1}{R T_1} = G_1 \qquad \frac{P_2 V_2}{R T_2} = G_2$$

$$G_1 - G_2 = \frac{P_1 V_1}{R T_1} - \frac{P_2 V_2}{R T_2}$$

then we have, $$\text{Flow} = \frac{V_1}{R}\left(\frac{P_1}{T_1} - \frac{P_2}{T_2}\right)$$

in which $V_1 = 89.647$ $R = 53{,}354$

P_1 $(100 + 14.7)\ 144$ $T_1 =$ Reading $+ 461$



$P_2 = (X + 14.7)\ 144$, in which X is pressure to which air fell.

T_2 = Reading + 461 G = weight of air.

Thus the weight of the entire flow is determined.

Divide this quantity by the time in minutes and the weight of flow per minute is determined.

Multiply this quantity by 12.39 and we have the air consumption in cubic feet of free air per minute.

NOTE: Above 60 lbs. pressure it was impossible to get the air consumption owing to the small size of the receiver tank.

All loads are given for one foot radius.

RESULTS OF TESTS.

5 lb. Pressure.

LOAD.	R.P.M.	FT. POUNDS.	H.P.
0	119	0	0
5	54	1696.41	.051
8	0	0	0

10 lb. Pressure.

0	164	0	0
5	121	3801.21	.115
10	50	3141.50	.095
13	0	0	0

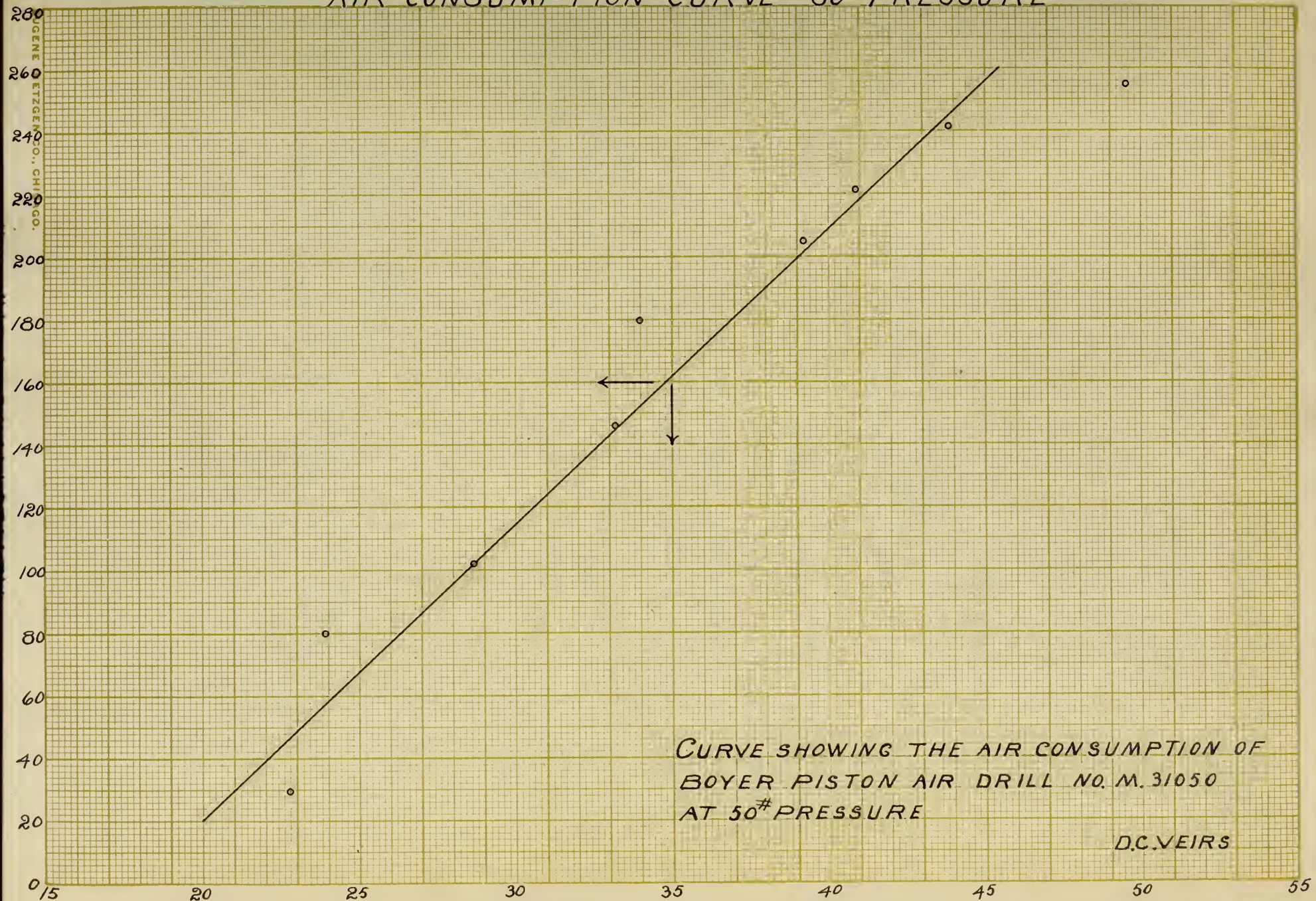
15 lb. Pressure.

0	188	0	0
5	163	5120.64	.155
10	117	7451.11	.226
15	31	2921.59	.088
18	0	0	0

LOAD	R.P.M.	FT. LBS.	H.P.	WT. OF AIR PER MIN.	CU. FT. FREE AIR PER MIN.
		20 lb. Pressure.			
0	212	0	0	1.56	19.38
5	184	5780.35	.175	1.45	17.96
10	146	9173.18	.278	1.24	15.36
15	89	8387.80	.254	.946	11.72
20	40	5024.40	.152	.627	7.76
23	0	0	0	0	0
		25 lb. Pressure.			
0	231	0	0		
5	213	6691.39	.202		
10	180	11309.40	.342		
15	141	13388.54	.405		
20	92	11560.72	.350		
25	50	7853.75	.238		
27	0	0	0		
		30 lb. Pressure.			
0	242	0	0	2.21	27.38
5	229	7194.03	.218	2.11	26.14
10	194	12189.02	.369	1.97	24.40
15	158	14890.71	.451	1.81	22.42
20	121	15104.86	.457	1.57	19.45
25	94	14765.05	.447	1.31	16.23
30	35	6597.15	.199	.96	11.86
32	0	0	0	0	0

LOAD	R.P.M.	FT. LBS.	H.P.	WT. OF AIR PER MIN.	CU. FT. FREE AIR PER MIN.
		35 lb. Pressure.			
0	248	0	0		
5	230	7225.45	.219		
10	200	12566.00	.380		
15	160	15079.20	.456		
20	151	18974.66	.575		
25	120	18849.00	.575		
30	77	14513.73	.439		
35	46	10115.63	.306		
37	0	0	0		
		40 lb. Pressure.			
0	250	0	0	2.89	35.80
5	232	7288.28	.220	2.81	34.81
10	203	12754.49	.386	2.59	32.09
15	165	15550.42	.471	2.33	28.86
20	160	20105.60	.609	1.92	23.78
25	125	19634.37	.595	1.86	23.04
30	82	15456.18	.468	1.65	20.44
35	58	12754.20	.386	1.45	17.96
40	0	0	0	0	0
		45 lb. Pressure.			
0	254	0	0		
5	238	7476.77	.226		
10	220	13823.60	.418		
15	203	19131.73	.579		
20	178	22367.48	.677		

AIR CONSUMPTION CURVE 50# PRESSURE



CURVE SHOWING THE AIR CONSUMPTION OF BOYER PISTON AIR DRILL NO. M. 31050 AT 50# PRESSURE

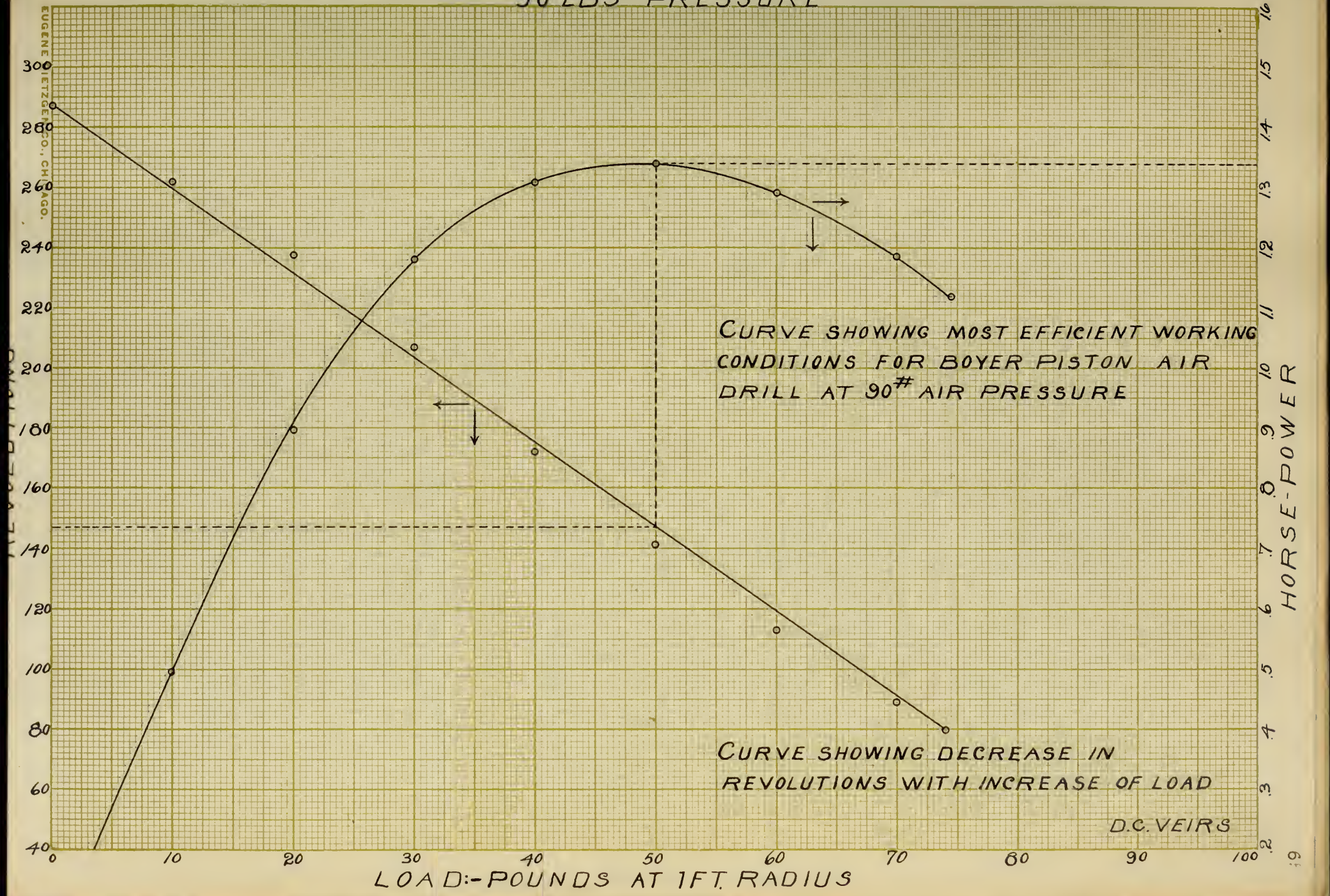
D.C. VEIRS

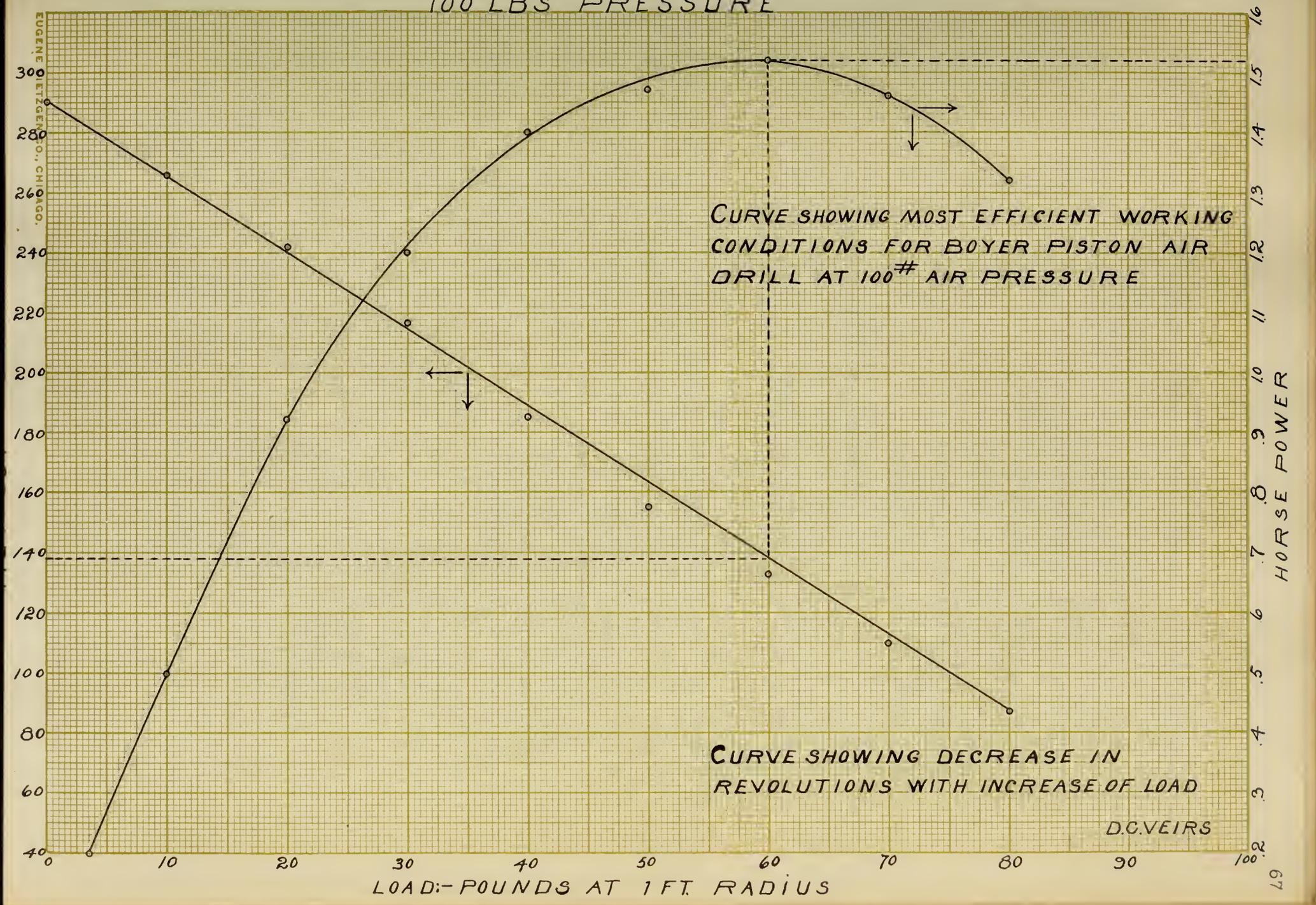
CUBIC FT. FREE AIR PER. MIN.

LOAD	R.P.M.	FT. LBS.	H.P.	WT. OF AIR PER MIN.	CU. FT. FREE AIR PER MIN.
		45 lb. Pressure. Continued.			
25	130	20419.75	.618		
30	90	16964.10	.514		
35	60	13194.30	.399		
40	30	7539.[illegible]	.2[illegible]		
42	0	0	0		
		50 lb. Pressure.			
0	255	0	0	4.00	49.56
5	241	757101	.[illegible]	3.54	43.86
10	221	13885.43	.420	3.30	40.88
15	205	19320.22	.585	3.17	39.27
20	180	22618.80	.685	2.75	34.07
25	146	19346.36	.586	2.68	33.20
30	102	18849.00	.571	2.31	28.62
35	80	17592.40	.533	1.93	23.91
40	35	8796.10	.266	1.84	22.79
45	0	0	0	0	0
		55 lb. Pressure.			
0	264	0	0		
10	222	13948.26	.422		
20	189	23749.74	.719		
30	128	24126.72	.731		
40	72	18095.04	.548		
50	42	13194.30	.399		
56	0	0	0		

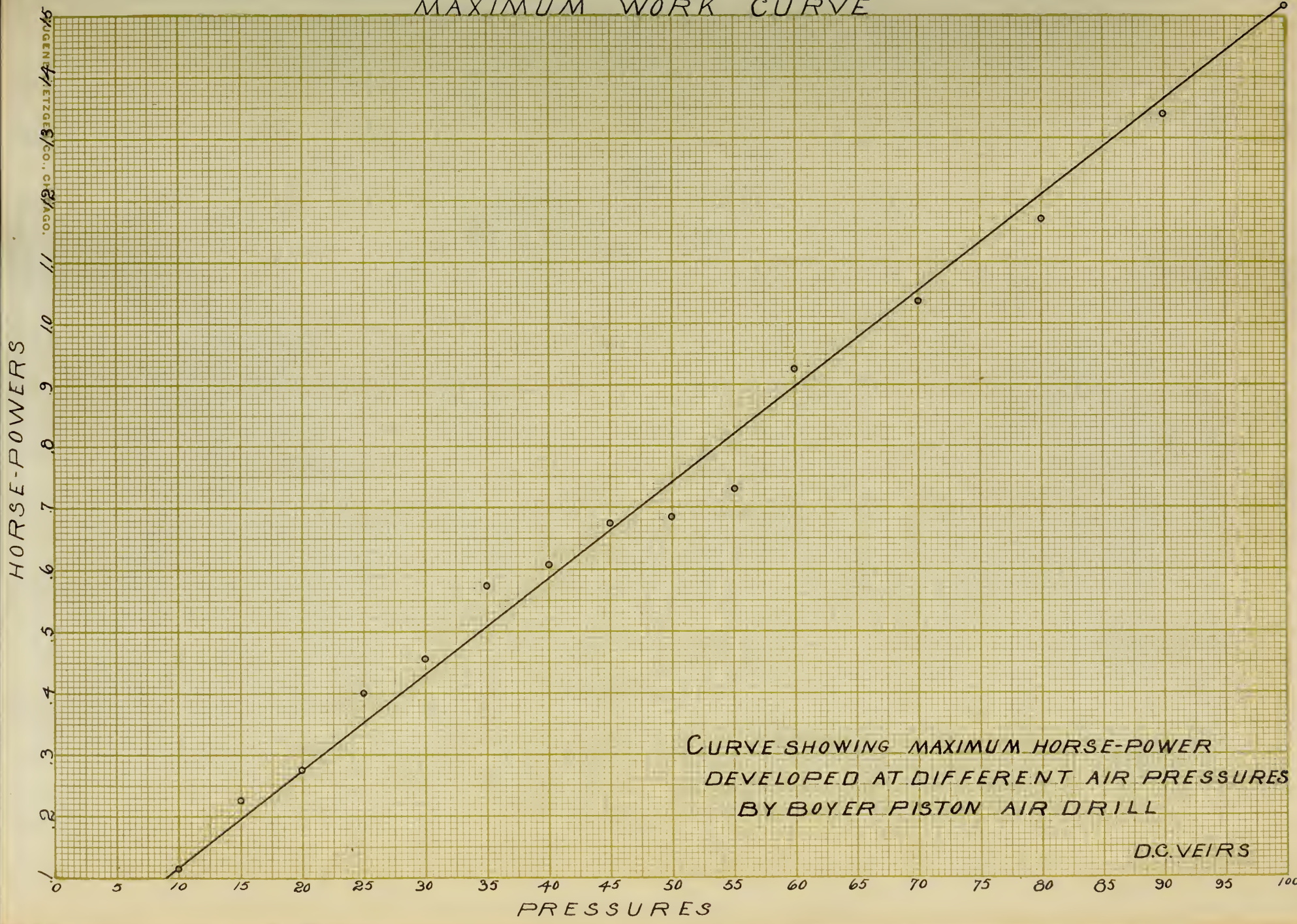
LOAD	R.P.M.	FT. LBS.	H.P.	WT. OF AIR PER MIN.	CU. FT. FREE AIR PER MIN.
		60 lb. Pressure.			
0	269	0	0	4.25	52.65
10	231	14488.73	.439	4.00	49.56
20	191	24001.06	.727	3.69	45.71
20	158	29781.42	.902	2.98	36.92
40	122	30661.04	.929	2.24	27.75
		70 lb. Pressure.			
0	283	0	0		
10	251	15773.33	.478		
20	219	27519.54	.833		
30	180	33928.20	1.028		
40	136	34179.52	1.035		
50	100	31415.0	.952		
54	87	29517.53	.894		

LOAD.	R.P.M.	FT. POUNDS.	H.P.
	80 lb. Pressure.		
0	285	0	0
10	256	16084.48	.487
20	228	28650.48	.868
30	194	36567.06	1.108
40	153	38451.96	1.165
50	123	38640.45	1.170
60	96	36190.08	1096
	90 lb. Pressure.		
0	287	0	0
10	262	16461.46	.498
20	238	29655.76	.898

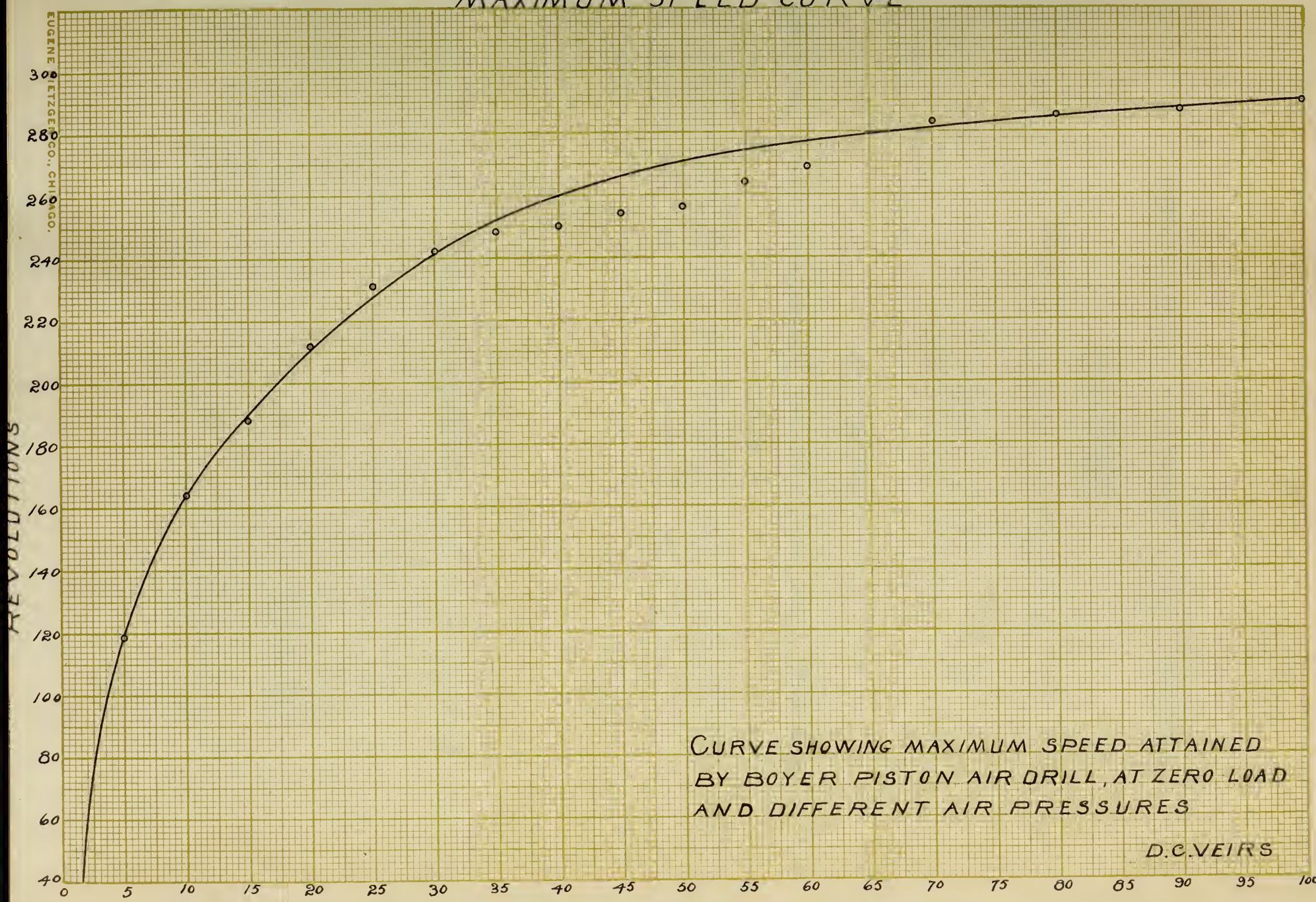

90 LBS PRESSURE
EUGENE DIETZGEN CO., CHICAGO.
300
280
260
240
220
200
180
160
140
120
100
80
60
40
0
10
20
30
40
50
60
70
80
90
100
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
HORSE-POWER
CURVE SHOWING MOST EFFICIENT WORKING CONDITIONS FOR BOYER PISTON AIR DRILL AT 90# AIR PRESSURE
CURVE SHOWING DECREASE IN REVOLUTIONS WITH INCREASE OF LOAD
D.C. VEIRS
LOAD:- POUNDS AT 1FT. RADIUS


100 LBS PRESSURE
EUGENE DIETZGEN CO., CHICAGO.
300
280
260
240
220
200
180
160
140
120
100
80
60
40
0
10
20
30
40
50
60
70
80
90
100
1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
HORSE POWER
CURVE SHOWING MOST EFFICIENT WORKING CONDITIONS FOR BOYER PISTON AIR DRILL AT 100# AIR PRESSURE
CURVE SHOWING DECREASE IN REVOLUTIONS WITH INCREASE OF LOAD
D.C.VEIRS
LOAD:- POUNDS AT 1 FT. RADIUS

LOAD	R.P.M.	FT. POUNDS.	H.P.
	90 lb. Pressure. Continued.		
30	207	39017.43	1.182
40	172	43227.04	1.309
50	141	44295.15	1.342
60	113	42598.74	1.290
70	89	39143.09	1.186
74	80	37195.36	1.128
	100 lb. Pressure.		
0	290	0	0
10	266	16712.78	.506
20	242	30409.72	.921
30	217	40902.33	1.209
40	185	46494.20	1.408
50	155	48693.25	1.475
60	133	50138.34	1.519
70	110	48379.10	1.466
80	87	43729.68	1.325


MAXIMUM WORK CURVE
HORSE-POWERS
PRESSURES
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
.1 .2 .3 .4 .5 .6 .7 .8 .9 1.0 1.1 1.2 1.3 1.4 1.5
CURVE SHOWING MAXIMUM HORSE-POWER
DEVELOPED AT DIFFERENT AIR PRESSURES
BY BOYER PISTON AIR DRILL
D.C. VEIRS

MAXIMUM SPEED CURVE



CURVE SHOWING MAXIMUM SPEED ATTAINED BY BOYER PISTON AIR DRILL, AT ZERO LOAD AND DIFFERENT AIR PRESSURES

D.C. VEIRS

WORKING RESULTS OF PNEUMATIC DRILLING MACHINES.

NO.1 MACHINE.

Drilling 1/2 in. hole through 1-1/4 in. mild steel plate 3 min 15 sec
" 3/4 " " " 1-1/4 " " " " 4 "
" 1 " " " 1-1/4 " " " " 6 " 25 "
" 1-1/4" " " 1-1/4 " " " " 8 " 10 "

NO.2 MACHINE.

Drilling 1/2 in. hole through 1-1/4 in. mild steel plate 5 min 20 sec
" 3/4 " " " 1-1/4 " " " " 7 "
" 1 " " " 1-1/4 " " " " 11 " 30 "
" 1-1/4" " " 1-1/4 " " " " 13 "

PNEUMATIC DRILLS.

Type.	Descriptive Number.	Weight.	Revolutions per minute, machines unloaded.	B. H. P.	Air-Consumption in Free Air.	Maximum Duty.
		lbs.			Cub. ft. per min.	
"Little Giant." Figs. 21 to 23.	0	45	125	2¼	45	3" holes in metal.
	1	35	190	1½	35	2" " " "
	2	19	250	1	25	1¼" " " "
	3	8	750	..	15	½" " " "
"Whitelaw." Figs. 26 and 27.	4	..	1,000	¼	15	¼" " " "
	6	14	720	¾	20	3" holes in soft wood
	7	20	250	1	25	For tube expanding.
	8	39	120	1½	30	3" holes in metal.
"Boyer." Figs. 28 to 30.	2	46	180	1¼	30	3" " " "
	3	41	240	1	25	1" " " "
	6	17	500	¾	20	¾" " " " 3" holes in soft wood

TESTS ON Q & C PNEUMATIC HAMMER.

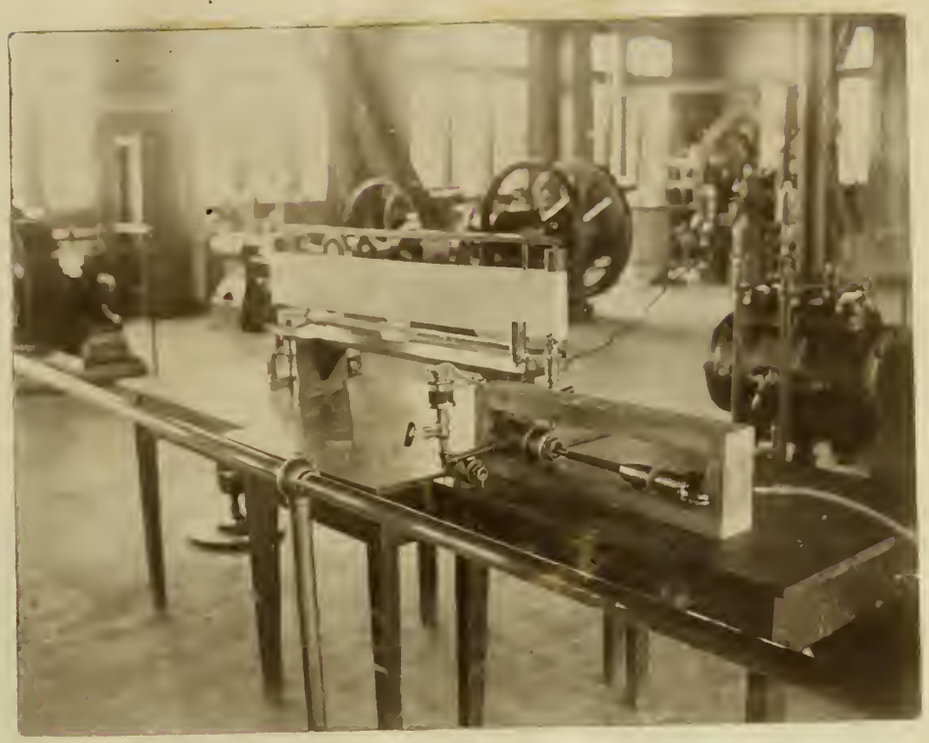
NO. C. 1352.

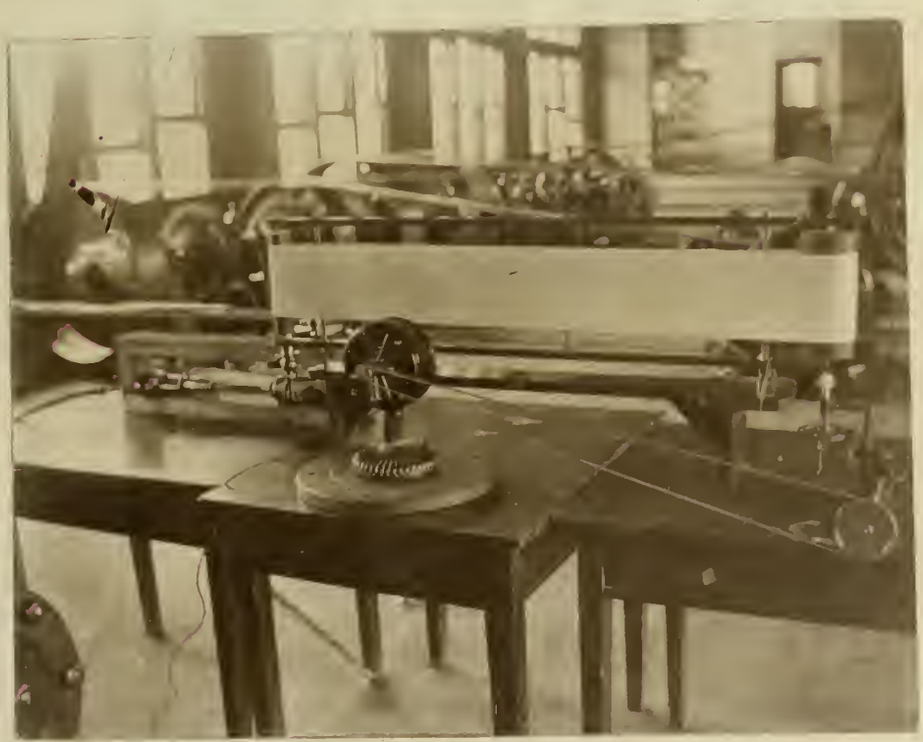
THE DETERMINATION OF NUMBER OF STROKES PER MINUTE.

Description of Apparatus.

The hammer was placed horizontally in one end of a frame, and in the other end an hydraulic cylinder was located. From the hydraulic cylinder, connections were made for a hand pressure oil pump and an indicator connection. Upon this latter connection an hydraulic indicator was placed. By means of the pressure pump sufficient pressure was kept in the cylinder to hold the piston continually against the blank tool of the hammer. The variation in pressure in the hydraulic cylinder, due to the hammer blows, caused pulsations to be transmitted to the indicator. These pulsations were recorded by means of a recording apparatus.

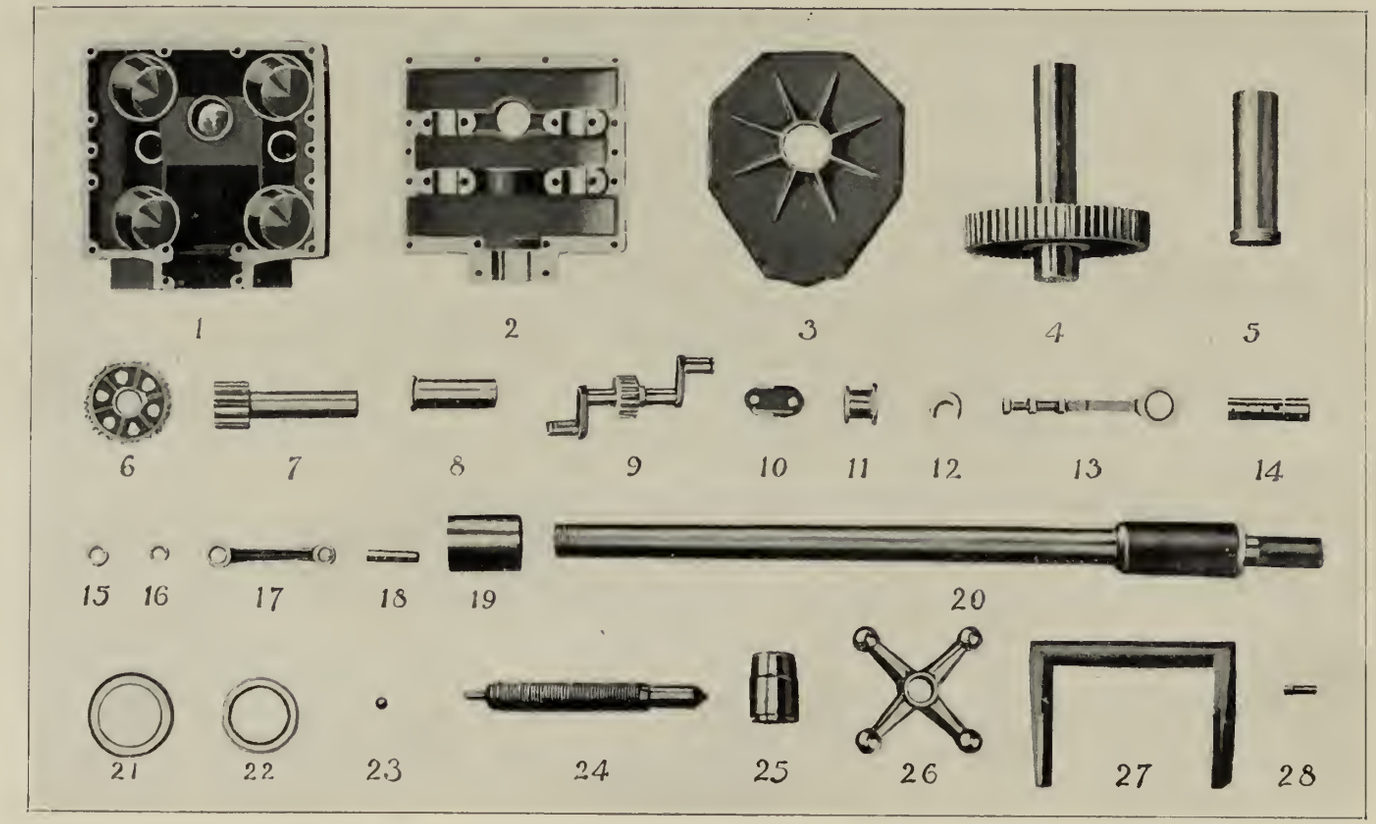
This apparatus consisted of a band of paper about nine feet long held upon two vertical rollers, which were driven by a small motor. Any desired speed was obtained by the regulation of a system of worm gears and friction disks. The indicator used was a Crosby; the piston area was 1/4 sq. inches. Soon after the tests began the original penal arm broke, due to the rapid vibrations. This was replaced by an arm made shorter and especially heavy at the dangerous section. The spring used for the lower pressures was 80 lb. As the pressure increased this was replaced by a 100 lb. spring, then a 120 lb., and for the higher pressures a 160 lb. spring was used. From the photographs the arrangements of the apparatus will be seen.



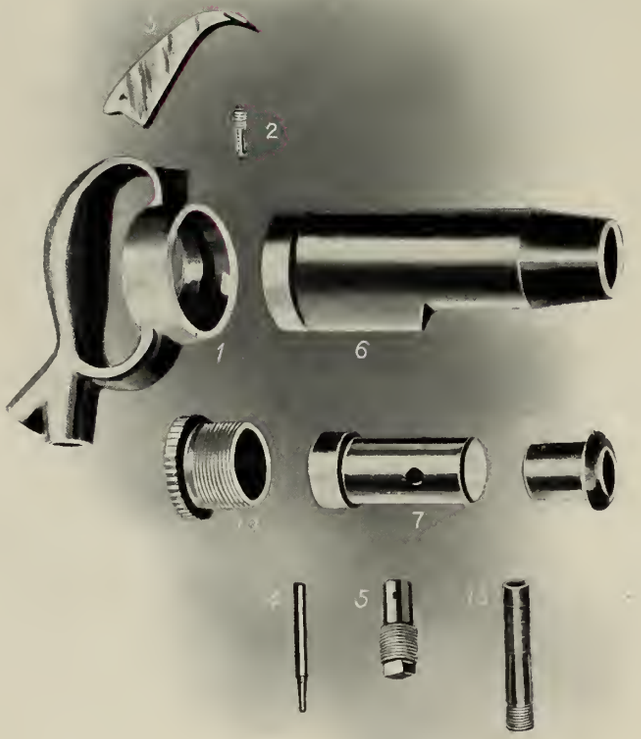


PARTS OF Q and C PNEUMATIC DRILLS

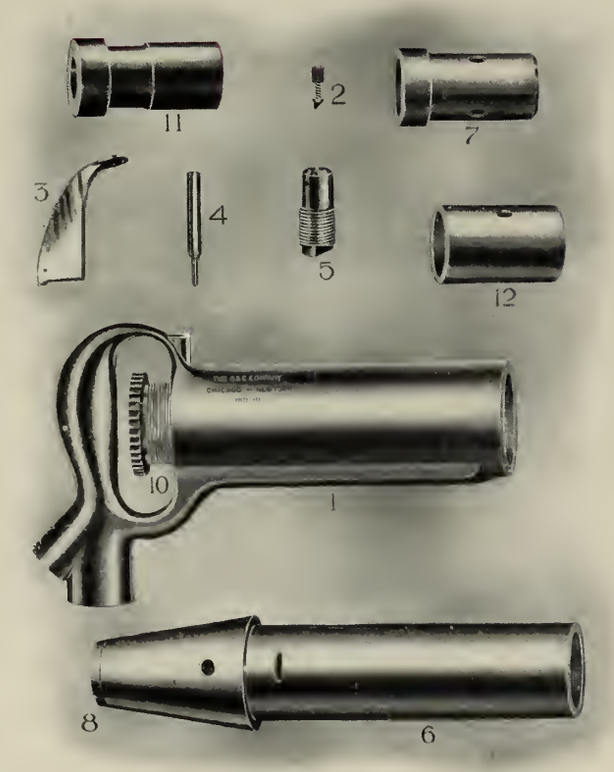
SIZES "B" AND "C"



PARTS OF Q and C PNEUMATIC HAMMERS



NEW



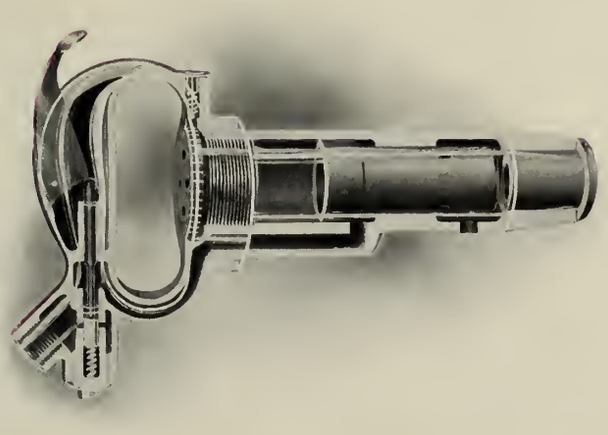
OLD

Q and C Hammer in Steel Works

No. 2 Q and C Riveter in Bridge Yard

Q and C Hammer in Machine Shop

Q and C Drill in Machine Shop

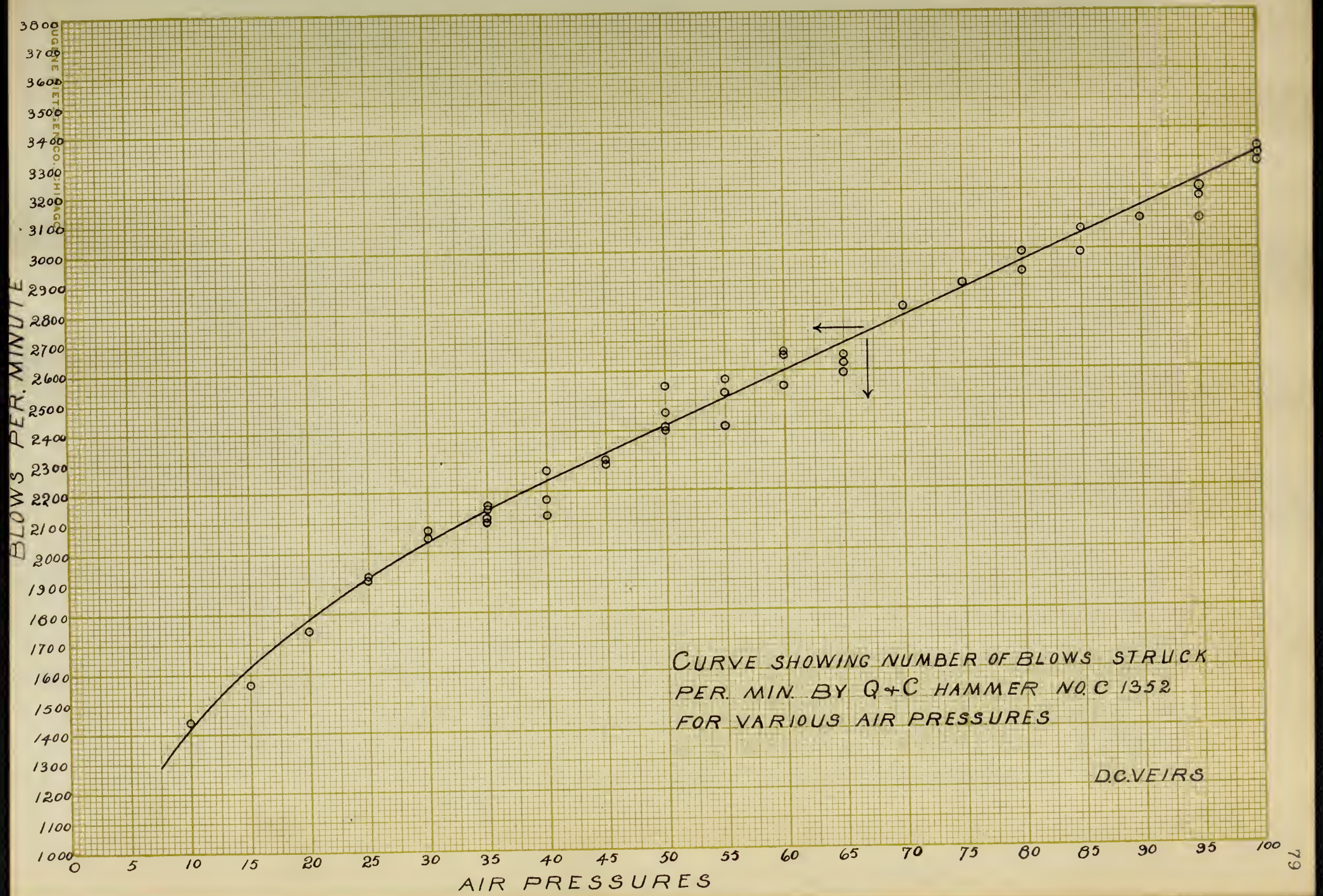


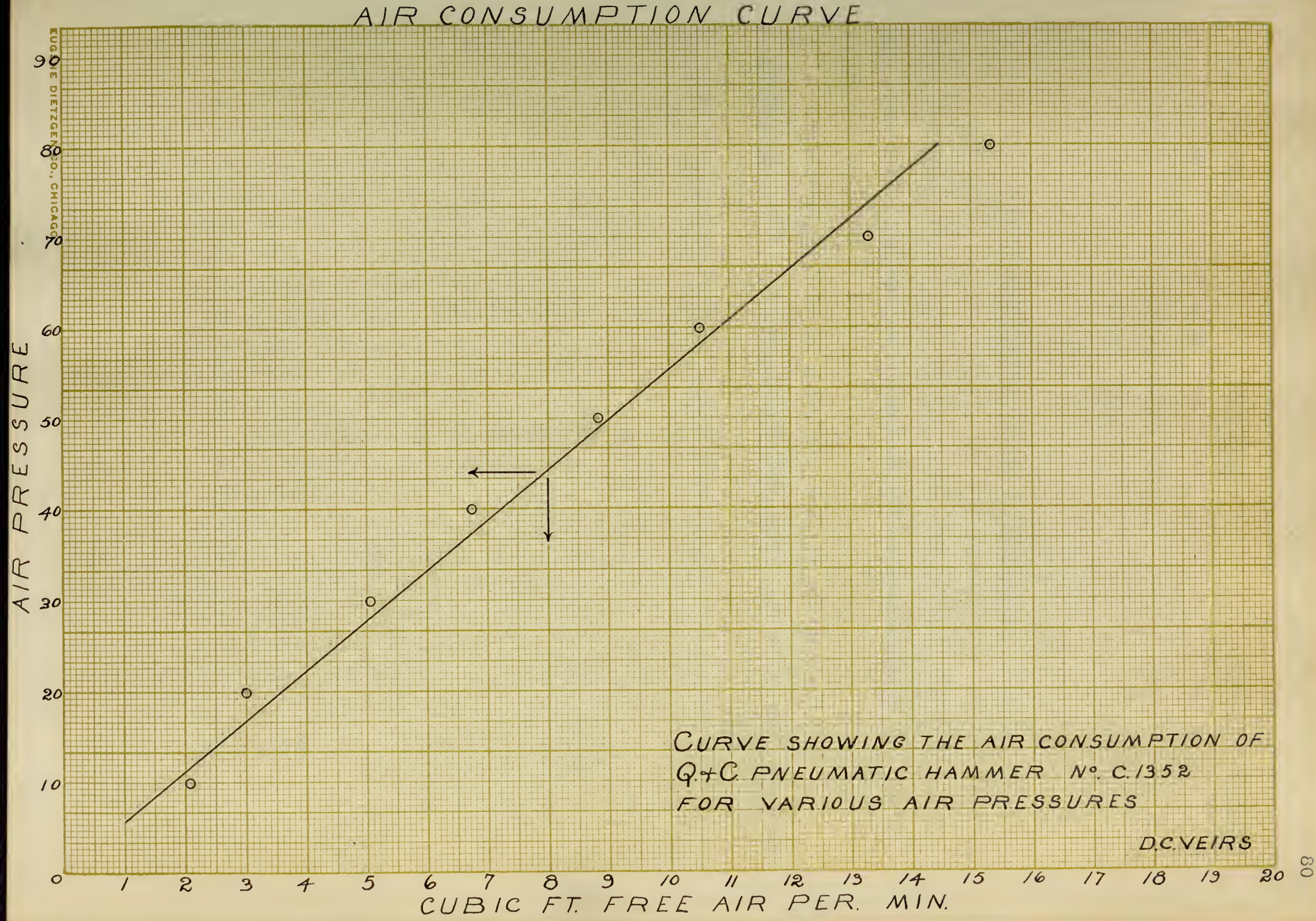
Operation.

The desired air pressure was kept constant on the hammer by means of the hand throttle valve on the out let pipe. The pressure was read on a gage placed between the throttle valve and the hammer. The desired pressure having been obtained, the indicator penal was held upon the moving paper for one minute. The time was caught by means of a stop watch. The speed of the paper was so regulated that it lacked only a very short distance of making one complete revolution per minute. The number of strokes in six inches was counted and this number was multiplied by the length of the record.

The following data and curve show the results of the tests.

AIR PRESSURE	PEADINGS	AVERAGE READING
10 lb.	1420	1420
15 "	1567	1567
20 "	1745	1745
25 "	1910, 1923	1915
30 "	2046, 2077	2060
35 "	2100, 2116, 2157, 2142	2130
40 "	2120, 2270, 2176	2188
45 "	2304, 2288	2296
50 "	2550, 2460, 2400, 2416	2456
55 "	2416, 2528, 2576	2506
60 "	2662, 2654, 2551	2622
65 "	2646, 2598, 2624	2622
70 "	2816	2816
75 "	2896	2896
80 "	2928, 2992	2960
85 "	2991, 3069	3030


EUGENE DIETZEN CO. CHICAGO
BLOWS PER. MINUTE
3800
3700
3600
3500
3400
3300
3200
3100
3000
2900
2800
2700
2600
2500
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
AIR PRESSURES
CURVE SHOWING NUMBER OF BLOWS STRUCK
PER. MIN. BY Q+C HAMMER NO. C 1352
FOR VARIOUS AIR PRESSURES
D.C. VEIRS


AIR CONSUMPTION CURVE
AIR PRESSURE
0
10
20
30
40
50
60
70
80
90
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
CUBIC FT. FREE AIR PER. MIN.
CURVE SHOWING THE AIR CONSUMPTION OF
Q+C. PNEUMATIC HAMMER No. C.1352
FOR VARIOUS AIR PRESSURES
D.C.VEIRS
EUGENE DIETZGEN CO., CHICAGO

AIR PRESSURE	READINGS	AVERAGE READING
90 lb.	3100	3100
95 "	3178, 3100, 3200	3159
100 "	3340, 3292, 3324	3318

THE DETERMINATION OF AIR CONSUMPTION.

The method of determining the air consumption was the same as that employed in the tests of the Loyer Air Drill. The hammer was run with different air pressures and the air consumption was determined for each.

The following table shows the results of the tests.

PRESSURES	WT. OF AIR PER. MIN.	CU. FT. FREE AIR PER. MIN.
10	.169 lb.	2.09
20	.242 "	3.00
30	.411 "	5.09
40	.548 "	6.78
50	.715 "	8.85
60	.848 "	10.50
70	1.075 "	13.31
80	1.240 "	15.36

TABLE I.—Table showing sizes, weights, and approximate air-consumption of Hammers.

Type.	Description Number.	Length of Stroke.	Diam. of Piston.	Weight of Piston.	Estimated Speed.	Air Consumption in Free Air	Weight of Hammer.
		ins.	ins.	ozs.	Blows per min.	cub. ft. per min.	lbs.
"Ross" Fig. 1.		$\frac{7}{8}$	$1\frac{3}{4}$	$2\frac{1}{2}$	11,000	30	$11\frac{1}{2}$
		$1\frac{3}{16}$	$1\frac{5}{8}$	2	"	25	$10\frac{3}{4}$
		$\frac{3}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	"	18	$10\frac{1}{2}$
		$1\frac{1}{16}$	$1\frac{3}{8}$	$1\frac{1}{2}$	"	15	$6\frac{1}{2}$
		$\frac{5}{8}$	$1\frac{1}{4}$	$1\frac{1}{4}$	"	13	6
"Q and C." Fig. 2	Single Hammer C	1	$1\frac{1}{2}$		10,000 to 15.000	12	$5\frac{3}{4}$
	Single Hammer D	$\frac{1}{2}$	$1\frac{1}{2}$			12	$5\frac{1}{4}$
	Single Hammer F	$\frac{1}{2}$	$1\frac{1}{4}$			10	$3\frac{1}{2}$
	Double Hammer A	1	$1\frac{3}{4}$			18	$10\frac{3}{4}$
	Double Hammer C	1	$1\frac{1}{2}$			15	$9\frac{1}{4}$
"Little Giant." Figs. 3 to 8	0	5	$1\frac{1}{8}$	20	1,200	20	16
	1	4	$1\frac{1}{8}$	16	1,500	15	12
	2	3	$1\frac{1}{8}$	14	2,000	15	$9\frac{1}{2}$
	3	$2\frac{1}{4}$	$1\frac{1}{8}$	14	2.000	15	$8\frac{1}{2}$
"Boyer." Fig. 9.	000	5	$1\frac{5}{16}$	34	1,000	20	26
	0	5	$1\frac{1}{16}$	$23\frac{1}{2}$	1,800	20	13
	1	4	$1\frac{1}{16}$	17	2,200	15	$9\frac{3}{4}$
	2	3	$1\frac{1}{16}$	13	2,600	15	$8\frac{1}{4}$
	3	$1\frac{3}{4}$	$1\frac{1}{16}$	13	3,000	12	$8\frac{1}{4}$
	B	2	$1\frac{3}{16}$	12	3,500 to 5.500	10	8
	BB	$1\frac{3}{4}$	$1\frac{1}{16}$	8		10	$6\frac{1}{2}$
	F	1	$\frac{3}{4}$	4		10	4
	U	$\frac{3}{4}$	$\frac{5}{8}$	3		10	3

SAMPLE RECORDS.

60 lbs., Air Pressure. Rate 2551 per. min.

85 lbs., Air Pressure. Rate 2991 per. min.

30 lbs., Air Pressure. Rate 2046 per. min.

40 lbs., Air Pressure. Rate 2120 per. min.

45 lbs., Air Pressure. Rate 2288 per. min.

T A B L E S

Exhibiting Relative Performance of Work

by

P N E U M A T I C T O O L S

and by

H A N D L A B O R.

H A N D
versus
A I R R I V E T I N G P O W E R.

(From American Engineer & R. R. Journal. Dec. 1900.)

The following data show the cost of hand driven rivets and those driven by the use of the Boyer Long Stroke Hammer on field work in the construction of Blast Furnaces, Hot Blast Stoves, Stacks and Stand Pipes. The average was arrived at after the expiration of several months work. Embodied in the statement covering the cost of the hammer driven rivets is only one twelfth of the expense in connection with the operation of the air plant, due to the fact that twelve hammers were in operation:

7/8" Rivets Driven in Day of 10 Hours by Hand

and

8 Hours by Boyer Long Stroke Hammer.

Hand Driven.

2 Strikers at $3. each---------- $6.

1 Holder-on at $3.50 each----------2.50

1 Heater at $1.25----------1.25

Total----------$9.75

Average number of rivets driven--375 at $9.75----------$0.0260 each

Hammer Driven

1 Machine Operator at $2.50----------$2.50

1 Holder-on " $2.50----------2.50

1 Heater " $1.50----------1.50

1/12th Salary of Eng'r--8 hrs. at 25¢- ----------$ .1666

" " " F'man " " " 17--1/2¢------- .1166

" cost of fuel at $2.50 per day---------- .2080

Total----------$6.9912

Average number of rivets driven--780 at $6.9912--------$0.0089 each.

Saving per rivet driven----------$0.0171 each.

The above shows a net saving of 62% in favor of the Boyer Long Stroke Hammer over hand driving, and does not take into consideration the saving in time effected by the shorter peroid required to complete the work.

The Following Table Shows the Saving Effected by the use of Pneumatic Tools.

(Table compiled by Mr. E. C. Schmidt, Instructor of R. R. Engineering. U. of I.)

These figures have been subjected to careful scrutiny before being accepted, and, for the conditions to which they apply, may be relied upon as accurate. The conditions they represent are normal and such as present themselves in all shops. All extraordinary records or test cases have been excluded and the results given may safely be applied in making deductions for conditions similar to those noted in the table.

TOOL	GENERAL CHARACTER OF WORK	SAVING	
		% of cost:	% of time
Pneumatic Hammer	Chipping	67 to 75	67 to 75
" "	Riveting on Mud Ring and Fire-box	67	-----
" "	Chipping Flue Sheet	84	75

TOOL	GENERAL CHARACTER OF WORK	SAVING	
		% of cost:	% of time
Pneumatic Hammer	Beading Flues	75	75
" "	General Boiler Shop Work.	60	----
" "	Cutting out broken fire-box stays	70	70
" "	Cutting off Stay-bolt Heads	58	----
Riveter	Boiler Riveting	66	50
Drill	Drilling Saddles	70	70
"	In general machine Shop Work:	75	75
"	Drilling for Stays	50	50
"	In General Boiler Shop Work	75	75
"	Facing Steam Pipes	75	75
"	Tapping for Stays	65	----
"	Reaming Crown Sheet	70	----
Breast Drill	General Work	90	90
Stay-bolt Nippers	Cutting off Stays	73 to 90	75 to 90
Driving-box Press	Pressing Brasses	68	-----
Paint Sprayer	Painting Box Cars	67	67
" "	" Car Trucks	87	87
Paint Burner	Cleaning off Passenger Cars	67	67
Sand Blast	Cleaning Tanks	90	83
Air Jet	Cleaning Cushions	50	50

The foreman of car construction of a leading railroad shop at Chicago, reports that by the use of the Whitelaw Wood Boring Machine his men are able to bore all the holes necessary in the erection of a standard coal car, 192 in number in 15 minutes. Allowing three minutes for shifting the air supply from one side of the car to an-

other, leaves a net period of 12 minutes allowed for the boring of these holes. Since this machine has been in use, the shop allowance per car for erection of this type of freight cars has been reduced to $10.00.

The Riter-Conley Manufacturing Company are using the long-stroke 13/16" by 9" riveting hammer of the Chicago Pneumatic Tool Company at the Laughlin Furnace, Pittsburg. They rivet three 1" plates with 1-1/8" rivets, and with hand work the ratio of loose rivets was 4 in 12, while the pneumatic riveter drives them four times as fast and with a ratio of one loose one in 18.

A cost of $4.32 for driving all the rivets, 253 in number, in a standard locomotive fire-box of the B.& O. SW. R. R. is a remarkable result. This work was recently accomplished in nine hours at a cost of 48 cents per hr. with a long stroke pneumatic riveter, made by the C. P. T. Co. The same work formerly required 15 hours of hand labor, at 73 cents per hour, giving a total cost $10.95 for hand work. If done by hand snapping the work required 12 hrs. and cost $7.56, at 63 cents per hr. Pneumatic tools in this case, therefore, saved $6.63 over hand riveting and $3.24 over hand snapping, the figures referring to labor charges only.

On basis of running three rivet hammers and forges equal cost for one hammer of----------$1.00

Oil for hammer, per day---------- .12

Labor two men, at $2.40 per day----------4.80

Labor one man, at $2.20 per day----------2.20

Total cost to operate one hammer per day----$8.12

Cost of riveting by hand.

Labor two men, at $2.40 per day	$4.80
" " " " $2.20 " "	4.40
Total cost of hand-rivet gang per day	$9.20

Men with pneumatic riveter will average 500 rivets per day for $8.12, or per hundred, $1.62.

Men with hand power average 250 rivets per day for $9.20, or per hundred, $3.68.

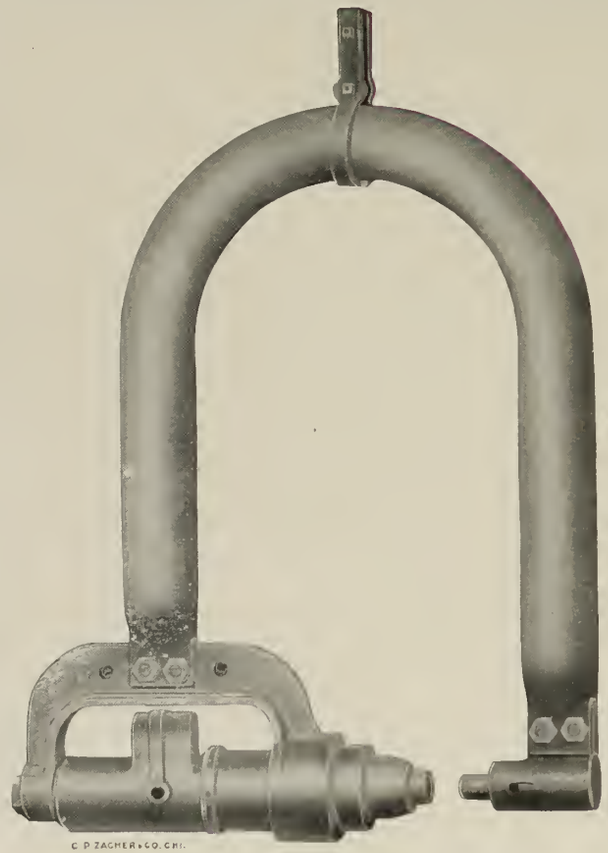
From the above figures it is seen that it costs more than double to drive rivets by hand than by using pneumatic tools.

COMPARISON OF COST BETWEEN MACHINE AND HAND-RIVETING AT CHICAGO SHIPYARDS.

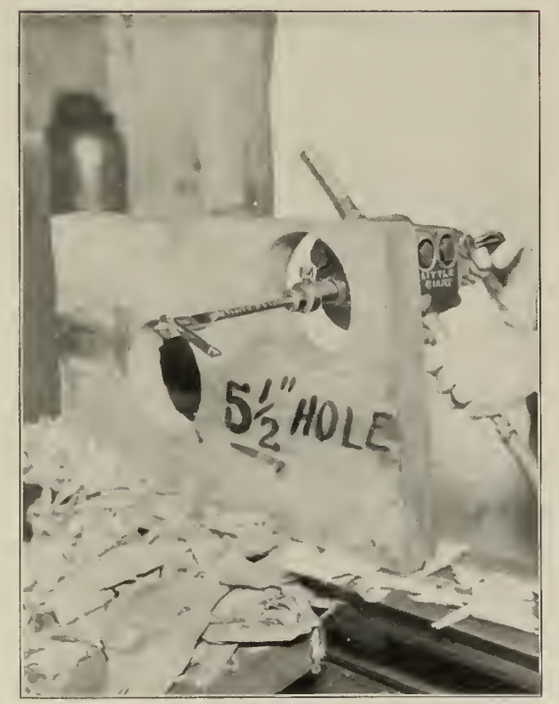
(Taken during three weeks ending 12 October, 1899.)

Distribution.	Number of Rivets.	Diam. of Rivets.	Machine Rate each.	Hand Rate each.
		Inch.	Cents.	Cents.
Keel	6,217	1	2½	4½
Shell	21,628	⅞	1¾	3½
Shell Margin (bilge single line)	1,122	⅞	3	4½
Longitudinals open	24,632	¾	1¼	2¾
C. V. K. Brackets	3,197	¾	1	3½
" "	—	—	1¼	3½
" "	—	—	1½	3½
Longitudinals under tank	664	¾	1¾	2¾
Longitudinal bars	2,989	¾	1¼	2¾
Tank-top Stiffeners	1,129	¾	2½	3½
Tank-top Margin	4,033	¾	1½	2¾
Tank-top Lugs	1,520	¾	1¾	3½
Tank-top Rider	3,209	¾	1¼	2¾
Tank-top	4,467	¾	1¼	2¾
C. V. K. Cross Vertical Kelson	12,723	¾	1	3
Hold Stringer	1,184	¾	1½	3
Floors	123	¾	1¼	3
Floors (odd)	5	¾	2	6
C. V. K. (odd)	38	¾	2	6
Bulkheads	1,318	¾	1¼	5
"	3,051	¾	1¾	3¼
"	231	⅝	1½	2½
Total	93,480			

Total cost by machine, $1,403.31. Average 1.50 cents each.
Total cost by hand would have been $2,986.87. Average 3.19 cents each.
Saving $1,583.56. Average 1.09 cents each.
Average cost of machine riveting was 47 per cent. of hand cost.



"Little Giant" Pneumatic Yoke Riveter.



No. 5 "Little Giant" Reversible Boring Full Capacity in Pine.

"Little Giant" Stay Bolt Nipper.

"LITTLE GIANT" TOOLS AND APPLIANCES.

No. 4 "Little Giant" Drill Grinding Seat.

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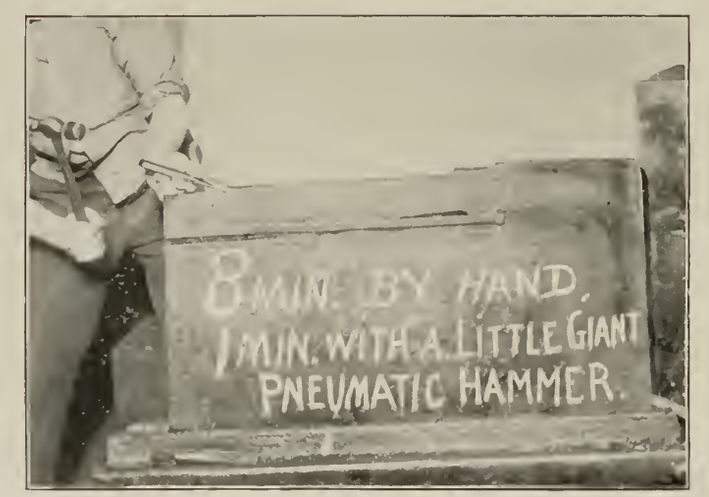
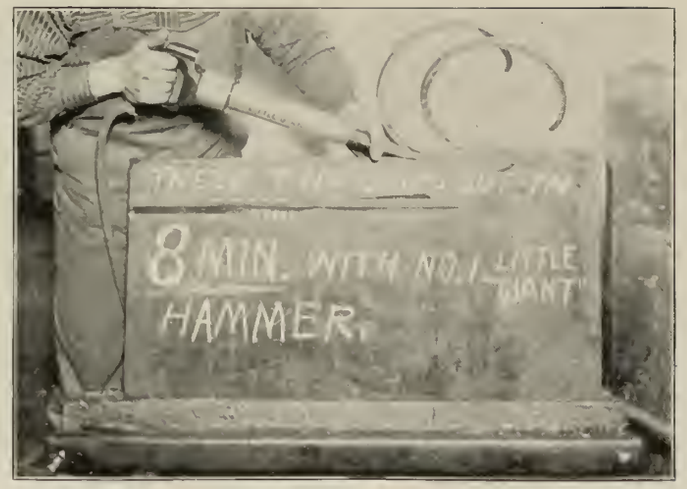


"Time is Money."

The only Pneumatic Hammer with regulator that will admit air as desired.



Combined length of the two chips, 45 inches.

One hour's trial is better than a thousand testimonials.

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TESTS MADE WITH "LITTLE GIANT" PNEUMATIC TOOLS, APRIL, 1900.

Type of Machine.	Work Done.	Time taken.		Average pressure of air used per sq. inch.
		Mins.	Secs.	Lbs.
2,000 lbs. Pneumatic Chain Hoist .	1,980 lbs. weight lifted 6 feet high.	1	0	72
No. 2 Drill . . .	Drilling 1-inch diameter holes through toughened steel armor-plate 4¼ inches thick.	9	15	70
No. 2 Drill, fitted with circular band-saw . . .	Cutting out in one piece a disc of wood 7 inches diameter by 1-inch thick for lamp-hole in railway carriage.	0	30	100
No. 12 Reversible Drill.	Expanding locomotive boiler-tubes, 1⅞ inches outside diameter.	0	30	70
No. 5 Reversible Drill.	Expanding 1-inch diameter steel condenser-tubes	0	30	70
No. 2 Hammer . .	Riveting 1-inch diameter copper stays, knocking down and finishing with snap.	2	30	71
No. 2 Hammer . .	Riveting 1-inch diameter wrought-iron studs cold.	1	0	70
No. 2 Hammer . .	Chipping Bessemer steel-plates ½-inch wide, the chipping taken off being ½-inch thick by 18 inches long, and weighing 11 lbs. 10 ozs. in one piece.	2	56	71

NOTE—The boiler-tube test was made at the Great Western Railway Works at Swindon, and the cutting lamp-holes at the London & North Western Railway Works at Wolverton.